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THE UNIVERSITY OF ALBERTA

DISTANCE AND LOCATION CUES IN MOTOR SHORT-TERM MEMORY

by

© CLAUDE ALAIN

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled " Distance and Location Cues in Motor Short Term Memory," submitted by Claude Alain in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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Abstract

The purpose of this series of studies was to determine how distance and location cues are used for the retention of kinesthetic information. The experimental task involved subjects reproducing distances or locations by displacing a cursor along a linear metal track.

Experiment I was an attempt to determine whether the same factors proposed by Posner (1966) in his acid-bath theory (time-in-store and similarity of the stored items) to explain the loss of verbal information, could also account for the loss of kinesthetic-distance information in short-term-memory. It was found that neither these two factors significantly affected recall performance.

The purpose of experiment II was to determine how long kinesthetic-location information could be retained. On the basis of the results, it was concluded that this type of information could be maintained intact for a period of twenty (20) seconds.

Experiment III was conducted to determine how Ss used their attention in order to retain kinesthetic-location information. The results were interpreted as indicating that Ss did not use their attention to cognitively transform the material to be stored. Rather, it is more likely that Ss merely concentrated on the K-location in its raw form.

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Chapter 1

Introduction

Without a memory system, learning would be impossible. In the past few years, numerous studies have been conducted investigating short-term memory (STM) using the method of reproduction for simple motor acts. Often these experiments have yielded apparently conflicting results.

Different factors have been proposed to explain these inconsistent results. Laabs (1971) suggested as one factor the failure to adequately control for the use of different cues, more specifically, the failure to distinguish between and control for movement distance and movement location cues.

If the sensory information from the kinesthetic receptors is of sufficient fidelity and meaningfulness that it can be used by the performer of motor skills, it is important to determine what type of kinesthetic cue is most conducive to the maintenance of the fidelity of kinesthetic information. Kinesthetic distance and kinesthetic location information appear to have different retention characteristics. Kinesthetic distance information is rapidly lost as a function of a test period, and further, removal of an attention during the retention interval does not hinder recall performance any more than a simple rest (Pfuhl and Monize, 1968; Quaney, 1967; Laabs, 1971). Alternatively,

R-location information is retained for at least a short period of time and removal of attention during this time has a detrimental effect on R-recall (Wilberg, 1969; Hughes, 1969; Keele and Ells, 1972; Laabs, 1971).

To further advance the understanding of how the human performer deals with the R-information, two questions should be answered: 1) For R-distance information: what are the constraints underlying its rapid loss of information? 2) For R-location: how long can the information be maintained and most importantly, how is this accomplished?

The research to be reported is an effort to answer these questions.

General problems

Experiment 1. R-distance information is lost quite rapidly over a very short rest interval (Posner and Konick, 1966; Posner, 1967; Laabs, 1971). Further, when its attention is partially or completely occupied by having its indulge in a verbal interpolated task during the retention interval, recall performance will not be affected more than by a simple rest. Consequently, if a kinesthetic-interpolated activity has an effect on recall performance which is significantly different from that of a simple rest, such an effect cannot be attributed simply to the removal of attention. Instead, the possibility of at least one other locus of interference must be entertained, likely a memory locus. Such a differential effect has been found by Williams, Beaver, Spencer

and Rundell (1969).

If K-interpolated material interferes with K-information already stored, what are the laws governing this interference? Posner (1966), in his acid bath theory, has proposed several factors that could account for the loss of verbal information. In the motor domain, experimental results from studies in which both distance and location cues are confounded, reveal that, similarity, one of the factors discussed by Posner, influences movement recall performance (Patrick, 1970; Craft and Hinrichs, 1971; Stelmach and Walsh, 1972).

This study will be an attempt to determine whether the same factors proposed by Posner in his acid bath theory (time-in-store and similarity of the material in store) account for the loss of K-information when distance is the only reliable cue.

Experiment II: Research conducted using K-location information has typically used short retention intervals (Wilberg, 1969; Dukes, 1970; Laabs, 1971; Keele and Ells, 1972). Because of that fact, it is not known how long the fidelity of K-location can be maintained and what is the pattern of the loss of movement-location as a function of time.

The purpose of this study is to describe the pattern of the loss of K-location over long rest periods. In addition to providing more information about K-location retention

characteristics, these results will serve as a basis upon which to determine the length of the retention interval to be used in the third experiment.

Experiment III: It has been shown that, for Ss to maintain the fidelity of K-location information, they have to devote their attention to the criterion material. If the attention is occupied during the retention interval, recall performance is greatly hindered (Wilberg, 1969; Hughes, 1969; Moyst, 1969; Keele and Ells, 1972; Laabs, 1971).

The next logical step is to ask how S uses his attention during the retention interval. Does he use his attention to transform the material into a more retainable form? Or does S simply concentrate on the sensory information as received without transforming it at all?

By manipulating the nature of the interpolated task (IT) it should be possible to demonstrate, with some degree of confidence, whether the criterion information is transformed for the purpose of retention. A verbal IT can be used to remove Ss attention during the retention interval. A kinesthetic-IT can be manipulated so as to predict a biasing effect at recall. If kinesthetic interpolated material has the same effect whether attended to or not, some support would be gained for the contention that K-location information is retained in an untransformed form since Ss would be unable to transform a K-interpolated location to which he did not attend.

This study will deal directly with these problems in

an attempt to determine how is K-location information maintained.

Definitions

Short-term memory (STM): "A system which loses information rapidly in the absence of sustained attention... (involving) about the first sixty seconds after presentation of a new stimulus. After that time, either the items are lost or they are transferred to a long-term memory system" (Fitts and Posner, 1967).

Kinesthesis (K): For the purpose of this study, kinesthesis is defined as being any internally response produced cue.

Kinesthetic-distance (K-distance): Distance is the only information cue available to the subject when location cues are made unreliable. Location cues are nullified by using several starting points at reproduction, all different from the standard movement's starting position and by keeping constant the distance to be reproduced.

Kinesthetic-location (K-location): Location is the only information cue available to the subject when distance cues are made unreliable. Distance cues are nullified by changing the distance to be moved between presentation and recall of the criterion location and keeping constant the position to be reproduced.

Absolute error (ABS): The unsigned difference between a criterion movement and its attempted reproduction by Ss.

Algebraic error (AE): The signed difference between a criterion movement and its attempted reproduction by Ss.

Constant error (CE): The average algebraic error.

Variable error (VE): The variability of the algebraic errors.

Limitations of the study

The study is limited by the ability of the subjects (Ss) to follow the prescribed instructions for the duration of each experimental session.

Delimitations of the study

The study is delimited by the sex, number, sampling and ages of the subjects.

Chapter 2

Related Literature

The related literature will be reviewed under three major sections: 1) those studies in which both location and distance cues were made available to the Ss 2) studies in which distance was the only reliable cue, and 3) studies in which location was the only reliable cue. Under each one of these major sections three questions will be considered: 1) how long is the information maintained over a rest interval? 2) what is the effect of removal of attention on K-recall performance? and 3) how does K-interpolated material influence K-recall.

Within each one of these question sub-sections, studies will always be reported according to the dependent variable(s) they used.

When distance and location cues are both reliable

Both cues are reliable when the starting and end points of a simple linear movement are the same at presentation and recall.

Effect of rest on recall performance

Studies in which absolute error is the dependent variable were reviewed first.

Adams and Dijkstra (1966) used retention intervals ranging from 5 to 120 seconds and observed that kinesthetic information becomes more and more unreliable as a function of time. These investigators did not mention, however, that performance after 5, 10 and 15 seconds was very stable (respectively 18.9 mm, 16.3 mm, and 19.6 mm) which indicated that K-information was somehow maintained for at least 15 seconds. Posner (1967a) reported a significant loss of information as a function of a 20 second rest period, and Stelmach and Barber (1970) found a similar effect after a 30 second rest. The design of this latter experiment makes its direct comparison to other studies questionable since before the 30 second retention interval, Ss had 4 trials at estimating the given criterion movement and, on each of these trials, they received verbal knowledge of their results. A graph (p. 233) representing both estimation trial scores and recall scores revealed that Ss recall performance was approximately the same as their performance on estimation trial number one.

Hence what was lost over the rest period was likely what was gained through verbal knowledge of their results.

Ascoli and Schmidt (1969) found a significant loss of K-information when recall performance after a 10 second rest was compared with recall performance after a 120 second rest interval. Stelmach (1969a) compared recall performance after 5, 15 and 50 seconds rest intervals; he reported that loss of K-information was greater after 50 seconds than it was after 5 or 15 seconds. The author did not mention whether the difference between 5 and 15 seconds was significant.

Sharp (1971) manipulated the information input load (2, 4 and 8 movements) using a two-dimensional joystick apparatus. He found no loss of K-information over a 15 second rest under all three levels of input load. Salmela (1972) conducted a similar experiment using the same apparatus. No statistically significant differences were found between immediate recall and performance after the 20 second rest.

While mean absolute error has been the most commonly used dependent variable in studies which had confounded cues, a few investigators have examined constant and variable error results.

Keele and Ells (1972) found no loss of K-information as a function of a 7 second rest period when both constant and variable errors were considered. Salmela (1972) reported similar findings for a 20 second rest period.

From these results, it can be observed that when both distance and location cues are available to the subject,

K-information is maintained for a short period of time.

Effect of verbal interpolated task on recall performance

Results obtained from absolute error measurement were reviewed first.

Posner (1967a) compared recall performance after a 20 second rest interval with performance after a 20 second retention interval filled with a digital classification task. There was a significant decrease in retention scores due to the rest period, but no difference was observed between performance after rest and that after the interpolated activity condition. Tannis (1972) used four digital interpolated tasks all varying in degree of difficulty as measured by the amount of information reduction they involved. All interpolated tasks were applied for 20 seconds. Her results indicated no differential effect due to task difficulty. Since she did not use an immediate recall condition nor an interpolated rest condition, it is not known whether the criterion information had been maintained intact or had completely decayed before the comparison was made at the end of the 20 second retention interval.

The next study to be reported in this section used both constant and variable errors as dependent variables.

Keele and Ells (1972) found that while there was no forgetting over a 7 second rest period, the introduction of a digital classification task between presentation and recall produced a significant change in reproduction performance.

Variable error was significantly increased for the interpolated condition and there was a significant retention interval X distance interaction for constant error. This interaction indicated that the phenomenon classically labelled "the range effect" was enhanced when an interpolated task was employed.

Several observations should be made from these experimental results. Firstly, in the study showing no loss of K-information as a function of rest (Keele and Ells, 1972), the interpolated activity had a significant effect on K-recall. This suggested that the covert mechanism which helps maintaining the fidelity of the criterion information can be interfered with. Secondly, two factors could account for the null effect of the interpolated task in the Posner (1967a) and Tannis (1972) studies. Both investigators used absolute error as their dependent variable. Laabs (1971), Pepper and Herman (1970) and Schutz and Roy (1973) have shown that, at times, absolute error could be insensitive to loss of K-information. A shift in subject's response biases or an increase in the variability of subject's responses could have occured without being detected by absolute error measurement. This possibility has been supported to some extent by the already discussed Keele and Ells study in which both variable and constant errors changed significantly because of the interpolated activity. The other factor that could have accounted for the null effect was that the criterion information could have been completely lost over the 20 second retention interval they used. While Posner showed a signifi-

cant decrease in recall performance after rest, Tannis' design did not allow such a comparison. The fact that she also used a 20 second retention interval and, in addition, presented her Ss with a much more difficult criterion task than did Posner, lends credibility to the possibility that the information might have been lost simply due to time-in-store and hence the null effect of IT.

It can be tentatively concluded that, when specific conditions are met i.e. appropriate length of retention interval and appropriate dependent variables, removal of Ss attention will significantly reduce recall performance.

Effect of kinesthetic interpolated activity on recall performance

Tannis (1972) compared the effect of 4 kinesthetic interpolated tasks on K-recall. All tasks lasted for 20 seconds and they all varied in the amount of information reduction they involved. When recall performance after each interpolated condition was compared there were no significant differences.

Sharp (1971) hypothesized that redundant kinesthetic tasks would not interfere with K-recall. He used two interpolated tasks varying in the degree of redundancy. The length of the retention interval was 15 seconds. He found no loss of information over the 15 second rest period and there was no effect due to the interpolated activity.

Both of the previous studies reported results obtained from absolute error measurement. The next studies to be

reviewed reported results obtained from constant error measurement.

Stelmach and Walsh (1972), Patrick (1970), and Craft and Hinrichs (1971) systematically varied the length of the interpolated movements. Their results showed that recall performance was biased in the direction of the interpolated movement.

Therefore it appears that a kinesthetic interpolated activity will affect recall performance when the length of an interpolated movement is systematically varied. This effect will be reflected by a change in Ss response bias in the direction of the length of the interpolated movement.

Summary

From this review three concluding statements can be tentatively proposed regarding K-information when both location and distance cues are available to the subject: 1) the information is maintained for a short period of time during a rest interval 2) when Ss attention is diverted from the criterion information recall performance will be significantly decreased if the length of the retention interval is not greater than the length of time it takes for the information to be lost (Keele and Ells, 1972) and 3) a kinesthetic interpolated movement will affect recall performance by producing a shift in Ss response biases in the direction of the length of the interpolated movement.

Does making both location and distance cues reliable

to the S produce an effect which can be explained on the basis of knowing the retention characteristics of each cue separately? The next section will review studies concerned with K-distance information only.

When distance is the only cue reliable

Effect of rest on the retention of kinesthetic distance

The first two studies to be reported here used absolute error as their dependent variable.

Posner and Konick (1966) measured recall performance after 0, 10, 20 and 30 second rest intervals. The effect of time was found to be significant at the .01 level of significance but the authors did not discuss where the difference(s) occurred. However, commenting on the basis of their graph (p. 81), there was a steep increase in error from 0 to 10 seconds while an asymptotic effect was observed between 10 and 20 seconds. Also, a decrease in error took place between 20 and 30 seconds. Posner (1967a) compared recall performance after 0 and 20 seconds. He found a 9.8 units of absolute error difference between both conditions which was significant at the .01 level of confidence.

This rapid loss of K-distance information is also evidenced by results obtained from constant and variable error measurements. Laabs (1971) compared immediate recall performance with that of after 12 seconds of rest. A significant change in constant error was observed in which Ss overshot short distances and undershot long distances to a greater extent as

a function of the delay. Also, the variability of Ss responses significantly increased over the 12 second rest period.

From these results it can be concluded that K-distance information could not be retained for a short period of time even when there was nothing restraining Ss from devoting their attention to the criterion material.

Effect of verbal IT on K-distance recall

Results obtained from absolute error measurement were reviewed first.

Williams et al (1969) compared recall performance after a 30 second rest and after three interpolated activities, all varying in degree of difficulty as measured by the amount of information reduction they involved. Aside from rest, the other interpolated tasks were recording, adding and classifying digits. All retention intervals were 30 seconds. They found no significant differential effect on recall performance due to the different interpolated conditions. Whether the criterion information was maintained over the 30 second rest period is not known since no immediate recall condition was included in the design. Hence the interpolated tasks may not have had an effect for this reason.

A similar experiment was conducted by Posner and Konick (1966). They used an immediate recall condition and three other retention intervals: 10, 20 and 30 seconds. Their interpolated tasks were the same as Williams et al (1969) and they found no significant differences due to the effect of

the four interpolated conditions. Since they had included an immediate recall condition in the design, it was possible to ascertain how well the criterion information had been maintained over the 10 second rest interval. Significant loss of information was observed over the rest period, occurring mostly during the first 10 seconds of rest.

Posner (1967a) used two retention conditions: rest for 20 seconds and digital classification for 20 seconds. He reported no significant increase in loss of K-information due to the interpolated activity. Further, the 20 second rest period produced a significant loss of information ($P < .01$) supporting Posner and Konick (1966).

These results, obtained from absolute error measurement, indicated that when distance is the only cue available to the Ss, the removal of Ss attention, by introducing a verbal interpolated task between presentation and recall, does not hinder recall performance more than a simple rest. This observation is further supported by results obtained from constant and variable error measurement.

Laabs (1971) compared recall performance after 12 seconds of rest and after 12 seconds of interpolated activity. There was no significant difference for the effect of these two conditions on either constant or variable error. In the same experiment, a significant loss of information was observed after the 12 second rest period as reflected by a change in constant error and an increase in variable error. Williams et al (1969) reported that none of their interpolated activi-

ties caused a significantly greater recall decrement than the 30 second rest period they used. There was no significant change in either constant or variable error.

From these results it can be suggested that the rapid loss of K-distance information over the rest period accounted for the lack of interpolated task effect since comparison between performance after the interpolated activity and recall performance after rest was often done after retention intervals that were longer than the time required for K-distance recall to be significantly affected. Further, the fact that a rapid loss of K-distance information occurred over short rest periods was not likely due to Ss inability to maintain their attention on the criterion material since K-location information is retained for longer periods of time which indicates that attention can be maintained for that period of time.

Effect of kinesthetic interpolated activity on K-distance recall

Williams et al (1969) had their Ss indulge in one of the three following retention interval conditions: rest, recording or adding. In the recording condition, Ss moved a lever to the left and right as indicated by the angles on the pages of a booklet. For the addition task, Ss moved the lever alternately left then right as in the preceding condition except that the third movement to the left was to be the sum of the previous pair of movements. All interpolated condi-

tions lasted for 30 seconds. They found that in the resting condition, the average absolute error was significantly less than the mean error for the two interpolated tasks conditions, but recording and adding did not differ significantly from one another in their effects on kinesthetic recall. The effect of the kinesthetic interpolated activity was reflected by an increase in both absolute and variable error measurement. No change in constant error was observed.

Summary

K-distance information is lost quite rapidly even when Ss could devote their attention to the criterion material. Further, when Ss attention was diverted during the retention interval, it did not induce more information loss than did a simple rest condition. In view of these facts, if an interpolated task having both attention diverting and memory interfering potentials affected recall performance more than a simple rest, the effect would most likely have been due to the memory component of the interpolated activity. For this reason, the conclusion proposed by Williams et al (1969), that the difference between recall performance after rest and that after interpolated tasks was due to the similarity of the interpolated task to the material in store, appears tenable.

What remains unanswered is how K-interpolated material interferes with the kinesthetic criterion material. If it is assumed that the critical factors in the loss of verbal informa-

tion have been outlined by Posner (1966) in his acid bath theory, the same factors could account for loss of K-distance information. More specifically, time-in-store and the similarity of the material in store appear to be factors to consider as being responsible for the loss of K-distance cues in motor short-term memory.

When location is the only reliable cue

Effect of rest on K-location recall

Results obtained from absolute error data were reviewed first.

Wilberg (1969) found no loss of information when reproduction after 10 seconds was compared to that of immediate recall. Similarly, Hughes (1969) reported no loss of information after a 20 second rest period. Dukes (1970), who compared recall performance after a 3 second delay (as immediate as possible in the context of his experiment) with performance after an 11 second rest, also found no effect due to the rest interval. Alternatively, Stelmach and Wilson (1970) found a significant loss of information ($P < .01$) after a 20 second rest period and Stelmach (1970), reported increasing error with longer retention intervals with an average of 5.4 degrees after 10 seconds and 6.3 degrees after 60 seconds yielding a significant difference ($P < .05$).

These conflicting results may be accounted for by an apparently important difference in the experimental procedures.

In the Wilberg (1969), Hughes (1969) and Dukes (1970) studies, Ss moved the lever to a criterion position then disengaged from the apparatus while E replaced the lever to a random position on the reproduction trial. In the Stelmach (1970) and Stelmach and Wilson (1970) studies, Ss moved the lever to a criterion position, then brought it back to a different position and remained there. This latter position was the starting point for the reproduction trial. This procedure made the distance moved from the criterion location to the position used as the starting point at reproduction a reliable cue. Therefore it is tentatively suggested that the results of the last two above mentioned studies might reflect K-recall performance when both distance and location cues are available to the Ss.

Results obtained from constant error measurement were reviewed next.

Dukes (1970) noted no significant difference in Ss response bias after an 11 second rest. Stelmach (1970; second experiment) obtained similar results when he compared recall performance after 12 seconds to that of after 40 seconds. Keele and Ells (1972) and Laabs (1971), using a 7 second rest and a 12 second rest, respectively, also observed no shift in Ss response bias as a function of the retention interval.

Loss of K-information can also be reflected by an increase in the variability of Ss responses. Keele and Ells (1972) and Laabs (1971) both reported no significant change in variable error as a function of the retention interval

(7 seconds and 12 seconds, respectively).

Therefore, from these studies, it can be concluded that the fidelity of K-location information was maintained for at least 12 seconds. This observation was valid for all three dependent variables used in these studies providing other potentially confounding design factors were controlled. Results obtained from absolute error measurement indicated that this type of information could be retained for a longer period of time. However, since changes in Ss response biases and increases in the variability of Ss responses could have occurred without being detected by absolute error measurement, this suggestion has to be interpreted with caution.

Nevertheless, it is important to determine how long K-location information can be retained and this must be ascertained using all three dependent variables mentioned above. The answer to this question has direct implications in regards to another crucial issue: how is K-location information maintained?

Effect of verbal interpolated task on recall performance

The first group of studies reviewed employed absolute error measurement.

Wilberg (1969) found a significant decrease in recall performance after 10 seconds of converting alphabet information to numeric form and summing the results during the retention interval. Hughes (1969) found similar results. An addition exercise for 10 seconds was sufficient to produce a significant

decrease in recall performance. Moyst (1969) also reported a significant effect of interpolated task condition when using a 10 second retention interval. None of these investigators found a significant decrease of recall performance as a function of rest.

Reviewed next were studies which reported constant and variable error measurements.

In their experiment, Keele and Ells (1972) had a location only condition. While there was no significant change for either constant or variable error after 7 seconds of rest, both of these dependent variables resulted in a significant effect after the interpolated activity. Laabs (1971) reported that, when mental activity was interpolated between presentation and recall, performance significantly decreased. The effect of the interpolated task mainly manifested itself as an increase in variable error.

From these experimental results two general conclusions were drawn: 1) K-location information was maintained for at least 12 seconds 2) If, for the length of this period, a mental task was introduced between presentation and recall the recall performance after this retention interval was significantly affected. These results were interpreted as indicating that attention was important in maintaining the fidelity of the criterion material.

What remains unanswered however is how does S use his attention to maintain the fidelity of K-location information? Does he strictly concentrate on the sensory information

as received or does he transform the movement location into a more retainable form?

Effect of kinesthetic interpolated activity on recall performance

Stelmach (1970) had his subjects engage in one of the same three retention interval conditions used by Williams et al (1969): rest, recording or adding. He found no difference between the three conditions and concluded that the amount of K-interpolated activity has little bearing on K-retention.

Stelmach and Wilson (1970) compared recall performance after two retention interval conditions: 20 seconds of rest and 20 seconds of kinesthetic interpolated movements. The interpolated condition led to a greater error at recall ($.86^{o}$ larger error $P < 0.05$).

Even had the results of the two foregoing studies been in agreement, the interpretation of these results would have been equivocal for the following reason. It would not be possible to point out whether this effect would have been due to the fact that the interpolated tasks were attention diverting or to the fact that they were of a kinesthetic nature.

Summary

K-location is maintained for at least 12 seconds. Further the covert mechanism used to retain the fidelity of the criterion information can be interfered with by diverting

Ss attention from the criterion material. The question that remains unanswered is how does S use his attention to retain K-location information?

Chapter 3

Methods and Procedures

In this chapter those aspects of the methodology common to all of the studies were outlined first, followed by the methodological details specific to each experiment.

General Methodology

Apparatus

The apparatus (see figure 1A) consisted of a 1 inch by 48 inch metal rule used as a track, mounted on a baseboard. A cursor, 1 inch by 1.5 inches was fitted on the metal track in such a way that it could be moved along the track with minimal friction. This cursor was used by S to make simple linear motor responses. A physical stop could be positioned on the track in order to define a distance or a location to be reproduced. This apparatus was fixed on a table top. The subject (S) was blindfolded throughout the experiment in order to eliminate visual cues. All delays were controlled by a Hunter decade interval timer, Model 111-B, series D.

The tasks

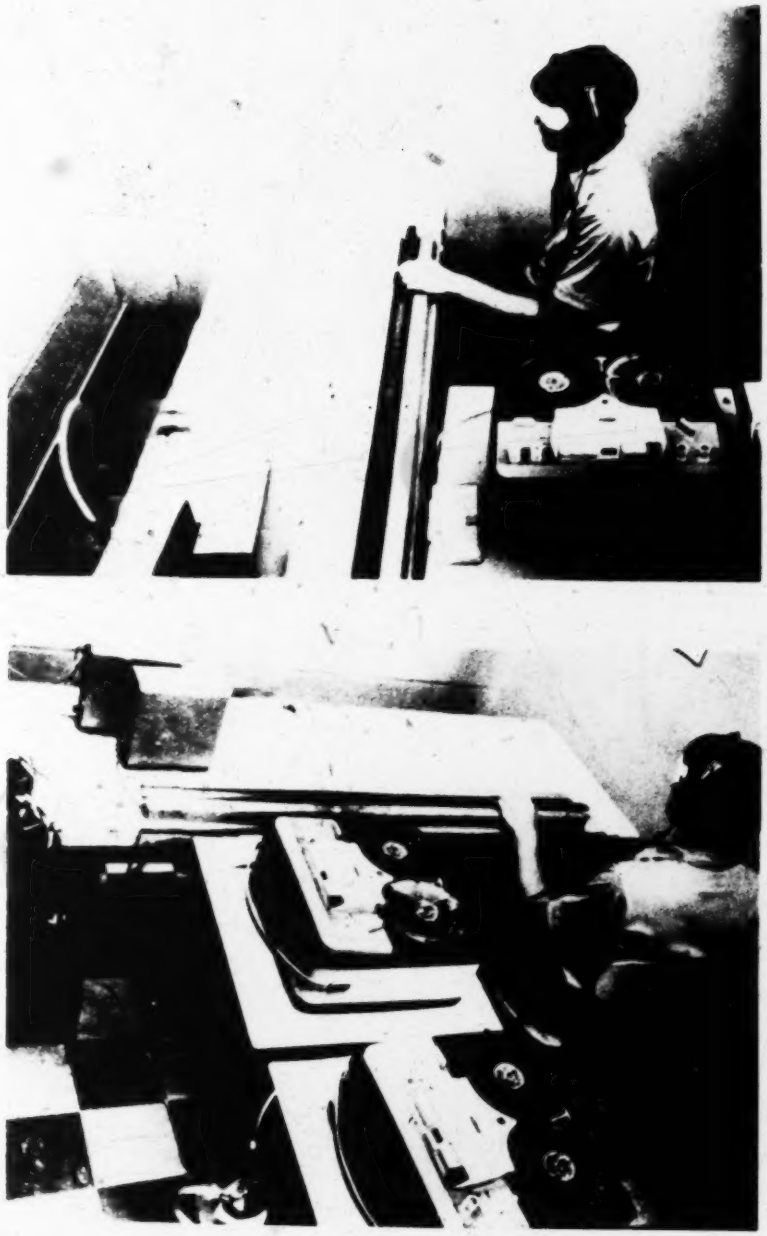
Two different experimental tasks were used, each one corresponding to the K-cue under investigation.

In the distance task, S moved the cursor until it hit

a physical stop, he then disengaged from the apparatus and brought his hand to a standard position in front of him. The experimenter (E) brought the cursor back to a different position and removed the stop. After the retention interval, S estimated the criterion distance he was given. The starting point at reproduction was never the same as the starting point at presentation rendering location cues unreliable. The starting position at presentation was randomly selected between points ranging from 0 to 12 inches from the origin of the track. At reproduction, the same procedure was applied with one restriction: the starting position at output could not fall within the starting point at input and the position on the track marking half the distance that was given at input. This additional precaution was used to ensure that the starting points at input and output would never be too close, therefore possibly inducing Ss to attempt to employ location cues in some fashion.

In the location task, the same procedures were followed with the exception that Ss task was to estimate the place at which he was stopped. Since the starting points at reproduction and at input were never the same, distance cues were unreliable. The distance moved to a location at input was either 4, 8 or 12 inches. At output, the distance moved was either 1/4 or 3/4 of the distance moved at input, providing Ss with 5 different output distances. This procedure was included to allow E to investigate some aspects of a possible relationship between distance and location cues.

FIGURE 1A VIEW OF SUBJECT AND APPARATUS



General procedures

Ss were instructed verbally and E ensured that they fully understood the task. The instructions emphasized the following task requirements: 1) No mediation was permitted during the input of the criterion movement 2) Ss were asked to maintain the same body position for presentation and recall on the same trial 3) When an interpolated task was introduced between the criterion movement presentation and recall, Ss were asked to execute the IT as well as possible, when the retention interval was unfilled, Ss were to concentrate on the criterion material 4) Ss were discouraged from using additional information other than the K-distance or K-location cues they were presented with.

The following events constituted a single trial. The experimental task under which S was to be tested was explained to him. S moved the cursor until it hit a stop which determined the distance or the location to be reproduced. After this input phase, S disengaged from the apparatus and the retention interval started during which S either sat still and rested or indulged in some interpolated activity. Before the termination of the retention interval E removed the stop, repositioned the cursor at a different starting point and led S hand to the cursor. S then attempted to recall and reproduce the K-distance or the K-location of the input phase.

Subjects

The same 10 subjects took part in the two experiments

concerned with location reproduction. A different group of 10 subjects was selected for the experiment on K-distance information. The subjects were chosen from the university of Alberta population and selection was made upon the students' availability and freedom from any apparent physical handicaps. Ages ranged from 15 to 28.

Dependent variables

Absolute error (ABS), constant error (CE) and variable error (VE) will be used as dependent variables. Definitions of these terms were presented in chapter 1.

Experiment 1

Purpose

The purpose of this experiment was to test whether the similarity of K-interpolated distances to the criterion distance and the time information was held in store were important factors contributing to the loss of movement distance information. A subsidiary purpose was to determine if a second distance could be inputed without damage while another one was in store.

Design

The experimental design was a treatment by subjects repeated measures design with 6 replications on all treatment conditions. The experimental conditions of interest were: the immediate recall of the criterion movement when distance was the only one presented at input; the immediate recall of one of

two distances presented at input (IT only); recall of the criterion distance after 15 seconds of rest when this distance was the only one presented at input; recall, after 15 seconds of delay, of one of two distances presented at input (IT + delay).

The order of experimental conditions were randomly assigned to the Ss.

Pairing

In both the IT + delay and IT only conditions, the input consisted of two distances presented successively. The pairing of these two distances was done systematically. Four (4) distances were used (7, 8, 10 and 12 inches) with every other distance: 7-8, 8-7, 7-10, 10-7, 7-12, 12-7, 8-10, 10-8, 8-12, 12-8, 10-12, 12-10. This pairing was repeated in order to obtain 24 pairs, each pair being the input distance for one particular trial. Therefore, S had 24 trials, one pair of input distances for each. This procedure allowed a comparison to be made between recall performance of a distance when only this distance was in store and recall performance of the same distance when an additional distance was presented at input. If similarity of material in store affected recall performance, a shift in Ss response biases could have resulted. Since it was suspected that the effect of two distances stored successively would produce a change in Ss response biases, only two distances could be affected, the shortest one and the longest one. The reason for this was as follows. The shortest

movement was paired with longer distances all the time while the longest one was always paired with shorter distances. The two intermediate distances were paired sometimes with shorter distances and other times with longer distances, therefore cancelling the possible biasing effect. For this reason, only the 7 inch and 12 inch distances were considered for analysis purposes.

Post-cuing

In order to ensure that Ss stored both distances for the purpose of recall, a post-cuing procedure was used. S was told which response to reproduce (either "first" or "second") after both the criterion movement and the interfering movement had been stored at input. Ss were required to reproduce the first and second distances with equal frequency.

Criterion distance vs interpolated distance

From the subject's viewpoint, the criterion distance was the one to be reproduced and it could have been any of the two distances presented at input. From the experimenter's viewpoint, the first distance was always considered to be the criterion distance and the second one the interpolated distance. Therefore, of the 24 responses given, 12 were criterion responses and 12 were considered reproductions of the interpolated movement The 4 distances were used as "criterion" 3 times each, each time paired with one of the other distances used (e.g. 7-8, 7-10, 7-12...) which provided 12 "criterion" responses. The

same distances were also used as interpolated distances 3 times each, each time paired with one of the other possible distances (e.g. 8-7, 10-7, 12-7...). This dichotomy between criterion and interpolated responses was necessary in order to discover if a second distance could be stored without interference while another one was already in store. Comparing recall performance of the same distances when they were put in first with that of when they were put in second was to indicate if the order of input resulted in differential recall performance.

Task

A distance reproduction task was used. A detailed description of this type of task can be found in the initial section of this chapter (p. 25).

Experiment 2

Purpose

The purpose of this study was two-fold: firstly to determine how long the fidelity of K-location was maintained; secondly, to study the effect of rest periods varying in length on the recall of movement-location. A subsidiary problem was to determine the effect the distance moved to a location had upon recall performance.

Design

The experimental design was a treatment by subjects repeated measures design with 5 replications. Time delay was

the factor of interest with 5 levels of 0, 10, 20, 30 and 40 seconds. Five different locations were used and under each experimental condition the Ss had 5 trials at each of the 5 locations. Therefore, Ss had 25 trials per condition.

The order of experimental conditions were randomly assigned to the Ss.

Task

The task used was a location reproduction task with procedures as described in a previous section of this chapter (p. 26).

Experiment 3

Purpose

The purpose of this study was to determine how S uses his attention to maintain the fidelity of movement-location.

Design

The experimental design used was a treatment by subjects repeated measures design with 5 replications for all subjects. Five experimental conditions were of interest in this study: immediate recall, 20 second rest, verbal interpolated task, kinesthetic interpolated task and verbal + kinesthetic interpolated task.

Five different locations were used and Ss had 5 trials with each location. Thus, every S had 25 trials under each of the experimental conditions. The order of the experimental

conditions was randomly assigned to the Ss.

Description of the treatments

In the immediate recall condition S moved to a location, stayed there for approximately 1 second and then disengaged from the apparatus. E then placed the cursor at a new starting position and lead S hand to the cursor at which time S attempted to move the cursor back to the position he was given at input. In the rest condition the same procedure was followed except that S reproduced the criterion location after a 20 second rest. Since the same 10 subjects that took part in experiment 2, were also used in this experiment, the data for these first two conditions was already available. In the verbal IT condition, the same procedure was followed except that, during the retention interval, Ss engaged in a verbal shadowing task (described below). The purpose of this task was to remove Ss attention from the criterion location for the length of the retention interval. In the kinesthetic IT condition, S moved to a criterion location and then was passively moved to an interpolated location where he remained for the length of the retention interval. The interpolated location was always 5 inches further than the criterion location. After the retention interval E disengaged S hand from the apparatus, replaced the cursor at another position and led S's hand back to the cursor. At this point S was to reproduce the criterion location. In the verbal + kinesthetic IT condition, S was presented with a criterion location after which he engaged in

the verbal IT. Immediately after he had started the interpolated activity, E passively moved his hand to the interpolated location which was also 5 inches further than the criterion location. A few seconds before the end of the retention interval, E gently removed S's hand from the apparatus, replaced the cursor at a new position and brought S's hand back to the cursor. The reason for moving the S's hand while he was engaged in the verbal IT was to ensure that S did not attend to the K-interpolated location.

The verbal interpolated task

Twenty five lists of 30 monosyllabic words were pre-taped on a Phillips tape recorder, type EL 3549 A/54 at the rate of one word every .60 seconds. The total time of a list was 18 seconds. The 2 second margin for the completion of the 20 second retention interval was needed because Ss verbal responses always lagged behind the input and hence when the tape finished S was still responding. To maximize the attention demands of the task, 5 target words were embedded in each list. The target words were animal names or numbers. One list had three animal names and two numbers while another had three numbers and two animal names. The S was provided with a set of headphones with which he heard the list. His task was to repeat every word of the list as it was presented and also identify every target word by tapping on a hard surface with a metal object.

Ss responses were all recorded on another Phillips tape

recorder, type EL 3549 A/54, and his performance was scored immediately after each experimental condition. S was required to repeat any trial in which he had done poorly on the IT. Any omission of a word or of a tapping response was considered an error.

Prior to the experiment, all Ss were given 15 practice trials on 15 different lists chosen at random. Every S was tested on all of the 25 lists as the primary task in order to obtain control information. This provided E with a basis of comparison with Ss performance on the same task when it was used as an IT. Thus it was possible to establish whether Ss attended to the interpolated material.

Statistical Analysis

The data for each individual study was analysed using 3 analyses of variance, one each for absolute error, constant error and variable error. Scheffe's test was used as a test between means for significant main effects.

The alpha level chosen was 0.01. The use of a repeated measures design increases the probability of treatment effects to be correlated. To balance the effect of heterogeneity of covariance, the Greenhouse and Geiser (1959) conservative degree of freedom were used.

Chapter 4

Analysis

Experiment 1

Hypotheses

H_1: Errors for immediate recall when the criterion movement (CM) was the only movement stored < errors for immediate recall of the criterion movement CM when both the criterion movement CM and an interpolated movement IT were stored for absolute, constant and variable error scores.

H_2: Errors for immediate recall when both CM and IT were stored < errors for recall after 15 seconds when both CM and IT were stored > errors for immediate recall when CM was the only movement stored for absolute, constant and variable error scores.

The first hypothesis was formed to determine if the immediate reproduction of a K-distance would change if, at input, a K-interpolated distance was presented just prior to or just after the criterion K-distance. Patrick (1970) and Craft and Hinrichs (1971) systematically varied the length of the interpolated movements. Their results showed that recall performance was biased in the direction of the interpolated movement. However, in these studies, both location and

distance cues were confounded.

The second hypothesis was formed to determine if a K-interpolated distance affected recall performance of a K-criterion distance when both were held in store for a period of 15 seconds. If the acid bath theory (Posner, 1966) holds true for K-distance information, the K-interpolated distance should have a significantly greater effect after 15 seconds than at immediate recall.

Results

Results related to the main problem of the experiment:

Three 3-way analyses of variance were carried out on the absolute, constant and variable error scores as the dependent variables (tables 1, 2 and 3 respectively). A statistical model after Edwards (1972, p. 273) was used to determine the experimental error to test the main effects.

The main effect of retention condition was significant at the 0.01 level of confidence for absolute and variable error scores. Further, when the Greenhouse and Geiser (1959) conservative degrees of freedom were used, the F ratios remained significant beyond the 0.05 level of confidence ($F(1,9) = 7.28$: $P < 0.025$) for absolute error scores and ($F(1,9) = 9.15$: $P < 0.025$) for variable error scores. The F ratio obtained from constant error measurements was not significant ($F(3,27) = 1.61$: $P > 0.05$). The graphs for the main effect of retention condition for absolute, constant and variable error were illustrated in

figures 1, 2 and 3 respectively.

The main effect of distance was significant at the 0.01 level of confidence for absolute error measurements ($F(1,9) = 24.56$: $P < 0.01$) and for variable error scores ($F(1,9) = 17.97$: $P < 0.01$). For constant error data, the F ratio reached 10.53 which was significant at the 0.025 level ($F(1,9) = 10.53$: $P < 0.025$).

With constant error scores a significant retention condition X distance interaction was obtained ($F(3,27) = 8.61$: $P < 0.01$). The graph for this interaction effect was illustrated in figure 4.

The means for the retention and distance conditions, based on 60 scores, were reported in appendix A, table 10 for absolute constant and variable error scores respectively.

Results related to the subsidiary problem of the experiment:

Three 3-way analyses of variance were conducted on the absolute, constant and variable error scores as the dependent variables (appendix A, tables 13, 14 and 15 respectively). The factor of interest was the order of presentation of two different distances. The purpose of this analysis was to determine if Ss recall performance of a particular distance was the same when the distance to be recalled was presented first from when it was presented second.

For this factor of interest, the analyses of variance yielded non significant F values for absolute, constant and variable error scores. No interaction was observed in anyone

Table 1

Three-way Analysis of Variance
Absolute Error

Source	Sum of Squares	df	Mean Squares	F
Retention condition (A)	876.19	3	292.06	7.28**
A X C	1,082.29	27	40.08	
Distances (B)	798.84	1	798.84	24.56**
B X C	292.66	9	32.52	
Subjects (C)	726.64	9	80.73	
A X B	83.01	3	27.66	0.81
A X B X C	910.99	27	33.74	

Table 2

Three-way Analysis of Variance
Constant Error

Source	Sum of Squares	df	Mean Squares	F
Retention condition (A)	273.83	3	91.28	1.61
A X C	1,522.78	27	56.39	
Distances (B)	2,610.61	1	2,610.61	10.53*
B X C	2,230.76	9	247.86	
Subjects (C)	6,164.06	9	684.89	
A X B	943.43	3	314.47	8.61**
A X B X C	985.68	27	36.50	

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 3

Three-way Analysis of Variance
Variable Error

Source	Sum of Squares		Mean Squares	F
Retention condition (A)	1,087,089.00	3	362,363.00	9.15**
A X C	1,068,172.00	27	39,561.92	
Distances (B)	945,620.69	1	945,620.69	17.97**
B X C	473,464.44	9	52,607.15	
Subjects (C)	581,315.81	9	64,590.64	
A X B	119,870.81	3	39,956.93	1.89
A X B X C	568,784.31	27	21,066.08	

** Significant at the 0.01 level

of those analyses.

Scheffé's test was applied to the means of the levels of retention condition for absolute and variable error data (appendix A, table 16). For both absolute and variable error scores, immediate recall led to significantly less error ($P < 0.01$) than recall after 15 seconds of rest. For variable error data, Ss performance after CM + IT immediate recall was better than after 15 seconds of rest ($P < 0.05$).

Discussion

To this point, it has been shown that K-distance information is lost quite rapidly even when S could devote his attention to the criterion material. Also, the similarity of a K-interpolated task to the material in store appears to be a source of interference as showed by recall performance. What remains unclear is how K-interpolated material interferes with the K-criterion material. This study was an attempt to determine if the factors proposed by Posner (1966) in his acid bath model could account for the loss of K-distance information.

Immediate recall performance

The immediate recall performance of the 7 inch and/or the 12 inch distance was not different when the criterion was stored with another distance. This is suggestive of the fact that the similarity of the stored material does not affect immediate recall performance.

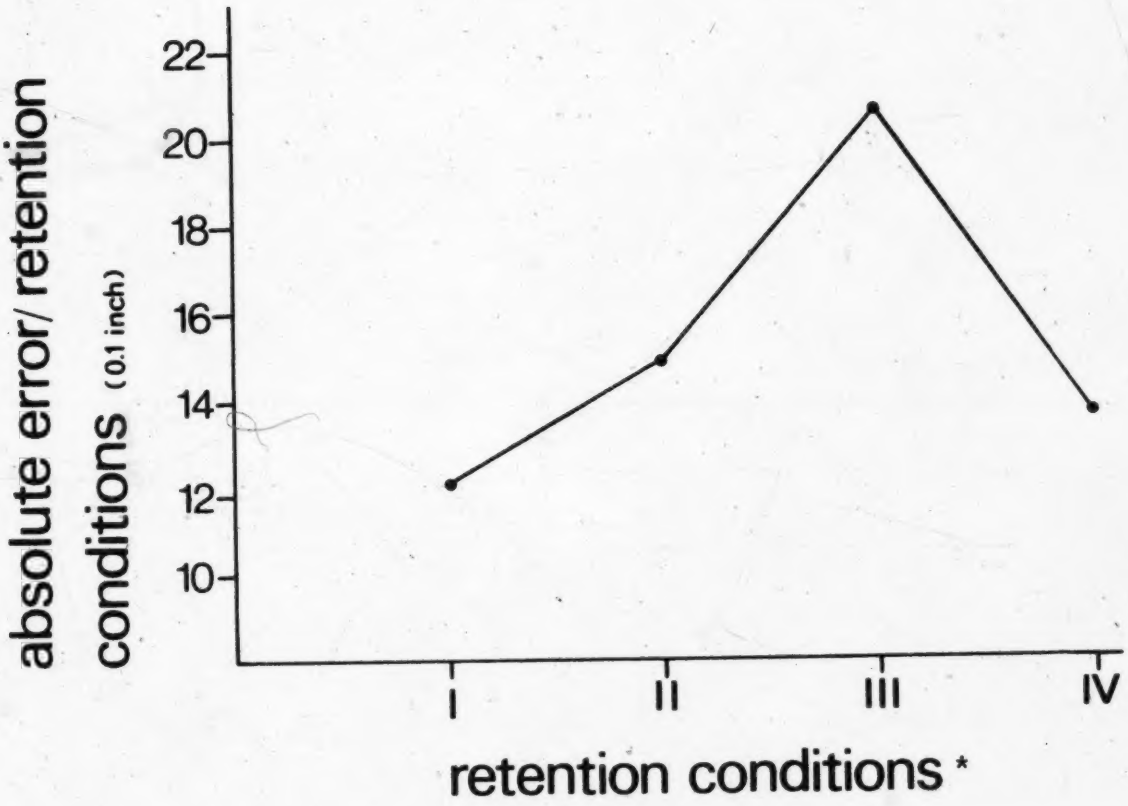


FIGURE 1: THE MEAN ABSOLUTE ERROR FOR Ss RECALL PERFORMANCE OF K-DISTANCE INFORMATION AS A FUNCTION OF RETENTION CONDITIONS.

* For all the figures of this experiment the retention conditions will be referred to as:

I- Immediate recall
II- CM + IT immediate recall
III- Recall after 15 seconds of rest
IV- CM + IT recall after 15 seconds.

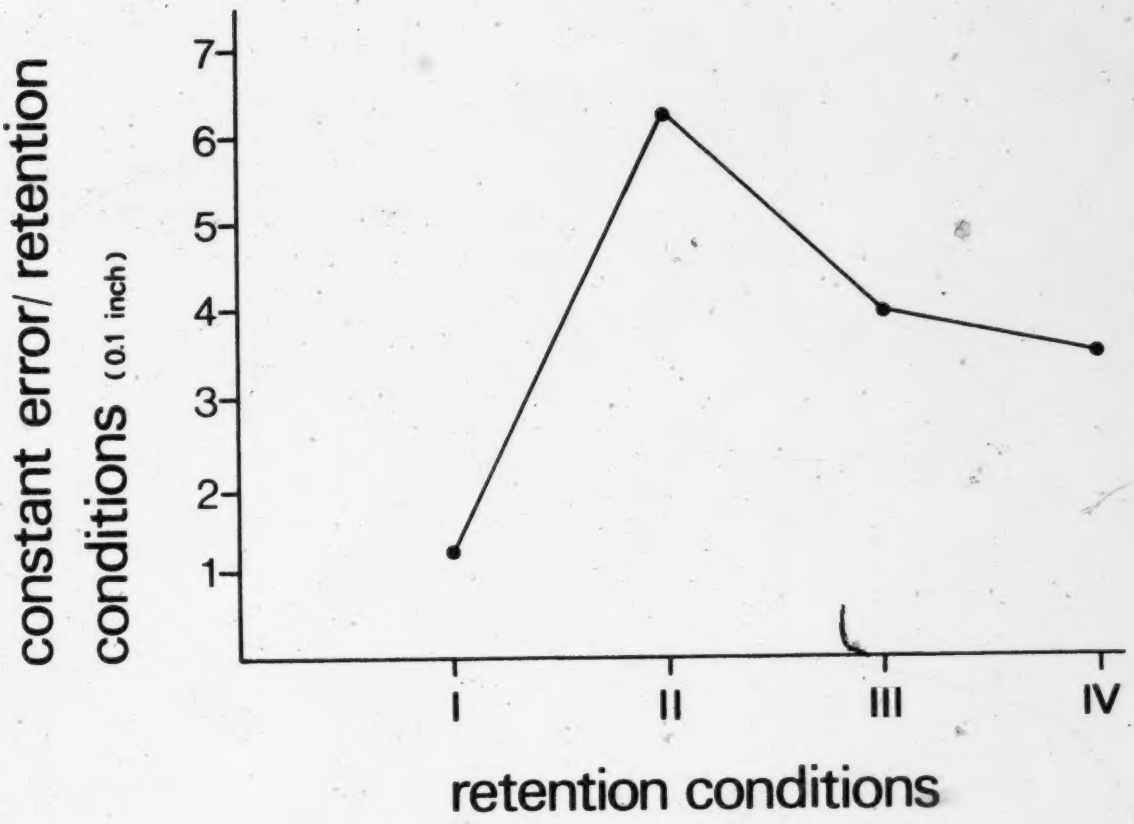


FIGURE 2: THE MEAN CONSTANT ERROR FOR Ss RECALL PERFORMANCE OF K-DISTANCE INFORMATION AS A FUNCTION OF RETENTION CONDITIONS.

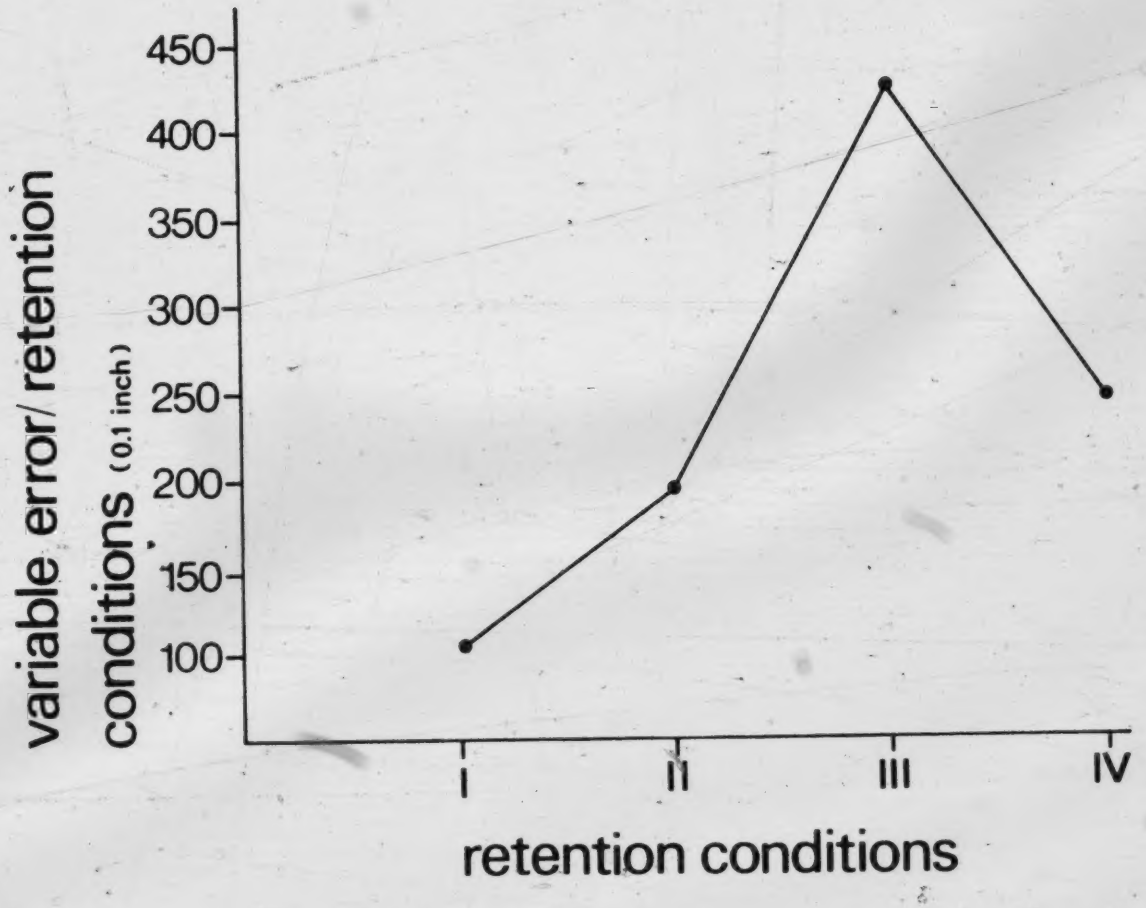


FIGURE 3: THE MEAN VARIABLE ERROR FOR Ss RECALL PERFORMANCE OF K-DISTANCE INFORMATION AS A FUNCTION OF RETENTION CONDITIONS.

The time-in-store factor: only one distance is stored.

The results of this study definitely show that time-in-store is one factor affecting the recall of K-distance information. Indeed, when only the criterion distance (either the 7 inch or the 12 inch distance) was stored, recall performance after 15 seconds of rest was statistically different than immediate recall performance for absolute and variable error scores. Therefore, time has an effect on the recall of K-distance information. This is in accordance with the results of earlier studies (Posner and Konick, 1966; Posner, 1967; Laabs, 1971). Further, this loss of information manifested itself as an increase in the variability of Ss responses indicating increased uncertainty in terms of the appropriate response to produce.

The time-in-store factor: two distances are stored together.

In proposing his acid bath theory, one reason Posner felt that time-in-store would enhance interference is that the information would decay over time-in-store and hence would be more susceptible to interference. Applied to K-distance information, this reasoning would predict that, if two distances were stored together, interference effects would be more apparent after a delay interval than at immediate recall.

The results of this study indicate that this was not the case. When two distances were stored together, the recall performance of the criterion distance after 15 seconds of rest

did not differ from that of immediate recall for all three dependent variables. Furthermore, since with constant error scores, a significant distance X retention conditions interaction was obtained, two separate analyses of variance were conducted on the constant error scores obtained from the recall performance of the 7 inch distance and the 12 inch distance respectively. The tables of these analyses were reported in appendix A (tables 17 and 18). In both cases, the F-ratios did not reach significance ($P > 0.01$). Such results are again indicative of the fact that time in store did not activate interference between the stored items as would have been predicted from Posner's acid bath theory.

Differential effect of time-in-store when only the criterion distance was stored as opposed to when two distances were stored

When two distances were stored together, time-in-store affected recall performance quite differently from when only the criterion distance was stored. This differential effect can be shown in two ways. First, a 15 second rest significantly affected recall performance when only one distance was stored as shown by increased variable error at recall while the same retention delay had no effect on the recall of the criterion distance when two distances were stored together. Second, the significant distance X retention conditions interaction obtained from constant error scores, confirms this differential effect. When only the criterion distance was

stored, Ss overshot the short criterion distance (7 inches) and undershot the long criterion distance (12 inches) both at immediate recall and at recall after 15 seconds. When the criterion distance was stored together with an interpolated distance, Ss response biases shifted in the opposite direction. The graph for this interaction effect was illustrated in figure 4. The consistency of this interaction is exemplified by the fact that 90% of the subjects were affected this way (appendix A, tables 11 and 12). Results obtained from both of these sources clearly indicate that time-in-store affected recall performance of the criterion distance quite differently when two distances were stored together as opposed to when only the criterion distance was stored.

Summarizing the above results, it appears that, although the time-in-store has a differential effect on recall performance of the criterion distance when two distances were stored as opposed to when only the criterion distance was stored, no difference was found between immediate recall and recall after 15 seconds of rest in the former condition. Based on this evidence, one could be tempted to conclude that the acid bath model proposed by Posner is not representative of the laws governing the loss of K-distance information. Rather, it is suggested here that the systematic differences obtained in the results when two distances were stored as opposed to when only the criterion distance was stored are representative of the fact that Ss used quite different strategies going from one condition to the other. Possible reasons for this are as

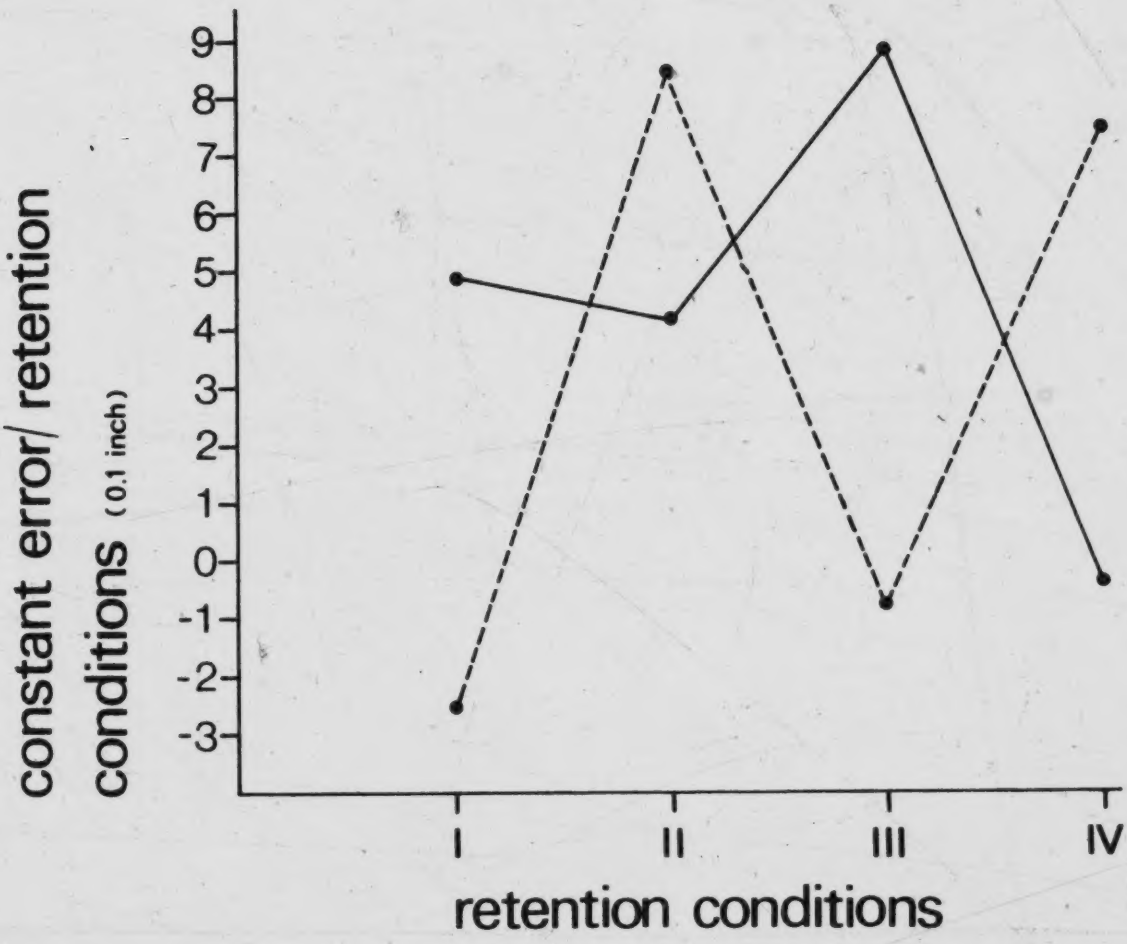


FIGURE 4: THE MEAN CONSTANT ERROR FOR Ss RECALL PERFORMANCE OF THE 7 INCH DISTANCE AND THE 12 INCH DISTANCE RESPECTIVELY AS A FUNCTION OF RETENTION CONDITIONS.

7 INCH DISTANCE

12 INCH DISTANCE

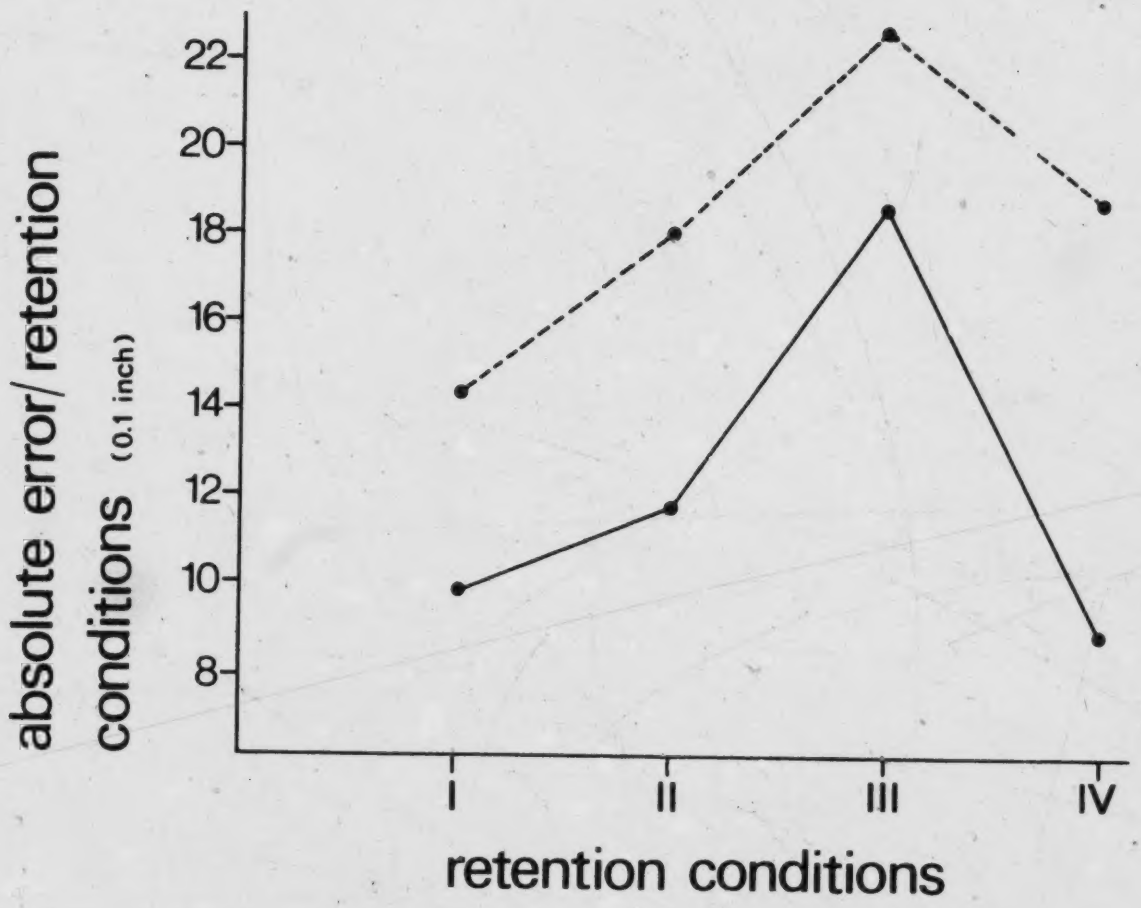


FIGURE 5: THE MEAN ABSOLUTE ERROR FOR Ss RECALL PERFORMANCE OF THE 7 INCH DISTANCE AND THE 12 INCH DISTANCE RESPECTIVELY AS A FUNCTION OF RETENTION CONDITIONS.

●———● 7 INCH DISTANCE

●- - - - -● 12 INCH DISTANCE

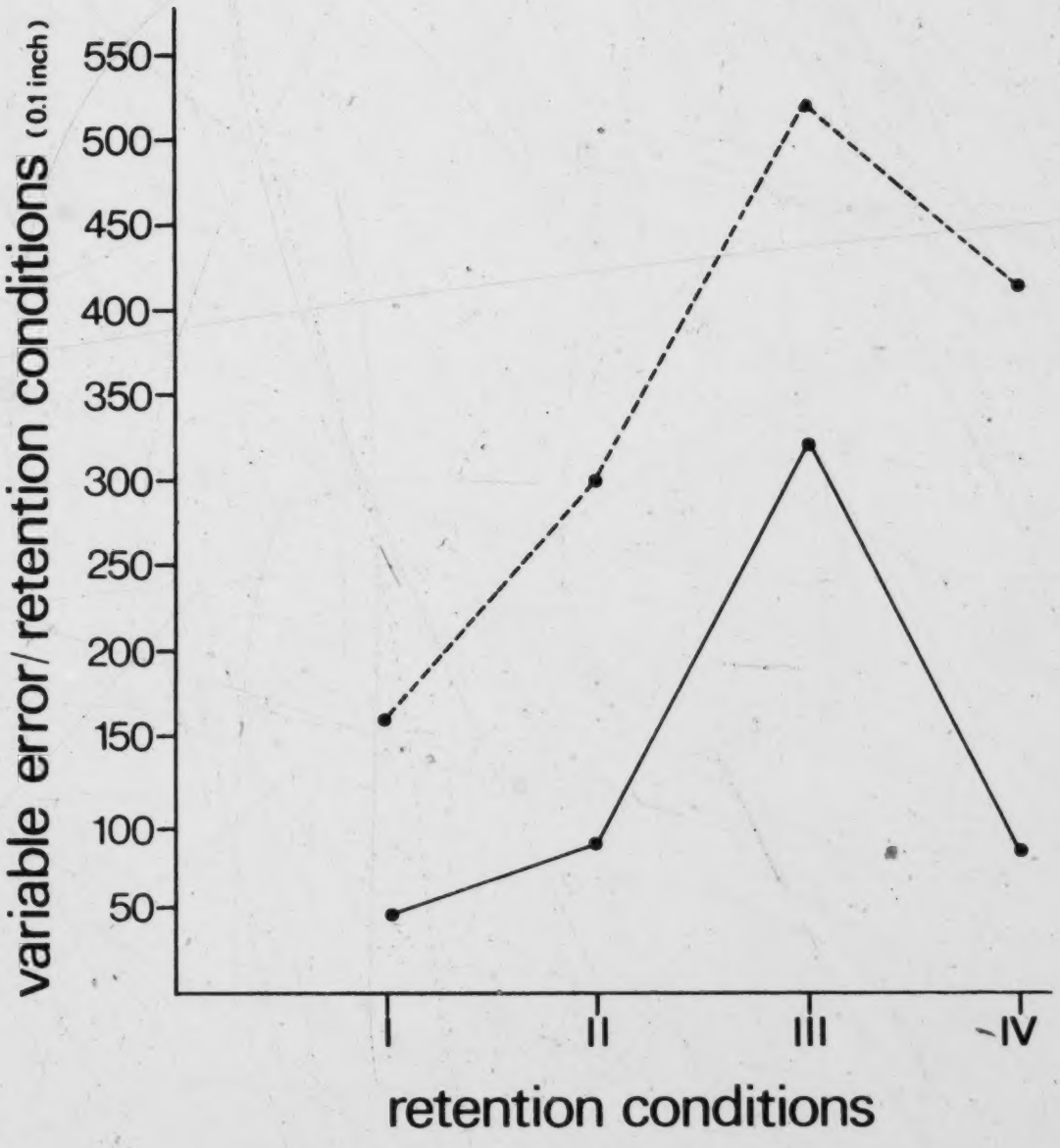


FIGURE 6: THE MEAN VARIABLE ERROR FOR Ss RECALL PERFORMANCE OF THE 7 INCH DISTANCE AND THE 12 INCH DISTANCE RESPECTIVELY AS A FUNCTION OF RETENTION CONDITIONS.

●———● 7 INCH DISTANCE

●- - - - - -● 12 INCH DISTANCE

follows.

Immediate recall of K-distance information has been showed to be imprecise in comparison with the recall of K-location information (Marteniuk, 1972). Also, as found in earlier studies (Posner and Konick, 1966; Posner, 1967; Laabs, 1971) K-distance information was rapidly lost as a function of a simple rest period while K-location information is retained for a short period. This would tend to suggest that Ss do not appear to be able to make judgments of distance but rather to be more efficient in making judgments in relationship to their bodies (Wilberg, 1973). Because of that fact, if, when dealing with K-distance information, the task would provide available information, Ss would operate on the basis of additional information to maximize their performance.

When only one distance was stored, Ss had to operate on the basis of K-distance information alone and hence the significant decrement in recall performance obtained in this experiment after a 15 second rest period. Alternately, when two distances were stored together at input, Ss had the opportunity to either operate on the basis of K-distance information alone or on the basis of a differential judgment between the two distances that were presented. For instance Ss could have used crude labels such as "the first one is the longer distance" and "the second one is the shorter distance"; when asked to reproduce the first or the second distance stored, Ss would make sure that what he had identified as being shorter was really shorter. The results tend to support such an interpre-

tation.

If, when both the criterion and interpolated distances were stored together, Ss would have used K-distance information alone, either an increase in variable error or a shift in Ss response biases would have happened since the same 15 second rest produced a significant recall decrement when only one distance was stored. Rather, Ss performance was very stable in terms of response variability and no significant shift in Ss response biases were obtained.

Along the same line of reasoning, earlier experiments in which both distance and location cues were available to the Ss (Patrick, 1970; Craft and Hinrichs, 1971) showed that, when only one K-movement was stored at input, the effect of an interpolated K-movement during a retention interval produced, at recall, a shift in Ss response biases in the direction of the interpolated movement. Based upon this available evidence, it was predicted that the storage of an interpolated distance together with the criterion distance, for the length of the retention interval, would lead to a similar assimilation effect. Surprisingly, the response biases shifted in the direction opposite to the one that was expected as showed by the significant distance X retention conditions interaction as illustrated in figure 4. Since interference from K-interpolated items has been showed to result in an assimilation effect when only one K-movement was stored, the surprising contrast effect obtained in this study when two distances were stored together can be interpreted as being the result of a differential strategy

used by Ss in these two conditions.

Discussion of the results related to the subsidiary problem

The results indicated that, when two K-distances were stored together, Ss recall performance of the criterion distance was the same whether it was presented first or second (appendix A, tables 13, 14 and 15). This implies that Ss storage capacity could accomodate at least two K-distances. This verification was necessary to determine whether or not, in the successive presentation of the two K-distances, the second one could be stored intact. It can be concluded that Ss were operating within the limits of the memory span and when two K-distances were presented to Ss, both distances were stored intact.

Experiment 2

Hypotheses

Three hypotheses were formulated in accordance with the related literature:

H_1: Errors for immediate recall = errors for recall after 10 seconds = errors for recall after 20 = seconds = errors for recall after 30 seconds = errors for recall after 40 seconds for absolute, constant and variable error scores.

H_2: Errors for recall when the distance moved at input was 4" = errors for recall when the distance moved at input was 8" = errors for recall when the distance moved at input was 12" for constant and variable error.

H_3: Errors for recall when the distance moved at output was 1/4 of the distance moved at input = errors for recall when the distance moved at output was 3/4 of the distance moved at input.

The first hypothesis was formed to test how long the fidelity of K-location information could be maintained when recall performance was assessed by absolute, constant and variable error measurements. The hypothesis was stated in the null form because, for this type of task, the maximum recall delay used when performance was evaluated by the three dependent

variables was 12 seconds (Laabs, 1971). No recall decrement was observed. However, results obtained from absolute error measurements alone (Hughes, 1969) indicate that this type of information could be retained for a longer period of time. Results from the present experiment will serve as a basis to select the proper length of recall delay to be used in experiment III. Also, additional information could be gained in terms of how K-location information is lost over long recall delays. Typically K-location information has been studied using rest intervals of 20 seconds or less.

The second and third hypotheses were formed in relation to the subsidiary problem of the experiment.

Results

Concerning the main problem of the experiment three 3-way analyses of variance were carried out on the absolute, constant and variable error scores as the dependent variables (tables 4, 5 and 6 respectively). A statistical model after Edwards (1972, p. 273) was used to determine the experimental error to test the main effects.

The main effect of recall delay was significant at the 0.01 level of confidence for absolute and variable error scores. Further, when the Greenhouse and Geiser (1959) conservative degrees of freedom were used, the F-ratios were still significant beyond the 0.01 level of significance ($F(1,9) = 16.93$ $P < 0.01$) and ($F(1,9) = 11.41$: $P < 0.01$) respectively. The F-ratio obtained from constant error measurements was not signi-

ficant ($F(4,36) = 1.34$: $P > 0.05$). The graphs for the main effect of length of delay for absolute, constant and variable error were illustrated in figures 7, 8 and 9 respectively. The main effect of location was significant for constant error only ($F(4,36) = 4.44$: $P < 0.01$). The graph showing this effect was illustrated in figure 10. The means for the different conditions of the experiment, based on 50 scores, were reported in appendix B, table 19.

In all three analyses the length of delay X location interaction was not statistically significant.

Scheffé's test was applied to the means of the levels of length delay for absolute and variable error scores (appendix B, table 20). For absolute and variable error scores, Scheffé's test yeilded statistically similar results: 0 seconds delay was different from 30 and 40 second delays; 10 second delay was different from 30 and 40 second delays; 20 second delay was different (at the 0.05 level only) from 30 second delay; and 20 second delay was different from 40 second delay.

Scheffé's test was also applied to the means of the levels of location for constant error scores (appendix B, table 21). Performance under the 12 inch location differed from that of under the 18 inch location.

Concerning the subsidiary problem of the experiment, two 3-way analyses of variance were carried out on constant and variable error scores (appendix B, tables 22 and 23 respectively). In this investigation, the two factors of

Table 4

Three-way Analysis of Variance
Absolute Error

Source	Sum of Squares	df	Mean Squares	F
Recall delays (A)	2,461.72	4	615.43	16.93**
A X C	1,308.24	36	36.34	
Locations (B)	103.56	4	25.89	1.09
B X C	854.35	36	23.73	
Subjects (C)	1,306.76	9	145.19	
A X B	296.31	16	18.52	1.21
A X B X C	2,186.93	144	15.18	

Table 5

Three-way Analysis of Variance
Constant Error

Source	Sum of Squares	df	Mean Squares	F
Recall delays (A)	434.07	4	108.51	1.34
A X C	2,901.49	36	80.59	
Locations (B)	1,395.75	4	348.93	4.44**
B X C	2,827.68	36	78.54	
Subjects (C)	9,078.86	9	1,008.72	
A X B	482.11	16	30.13	1.23
A X B X C	3,500.20	144	24.30	

** Significant at the 0.01 level

Table 6

Three-way Analysis of Variance
Variable Error

Source	Sum of Squares	df	Mean Squares	F
Recall delays (A)	830,699.99	4	207,674.87	11.41**
A X C	654,674.12	36	18,185.39	
Locations (B)	41,003.55	4	10,250.88	1.44
B X C	255,499.37	36	7,097.20	
Subjects (C)	733,148.00	9	81,460.87	
A X B	154,859.75	16	9,678.73	1.31
A X B X C	1,061,168.00	144	7,369.21	

** Significant at the 0.01 level

interest were 1) the distance moved to the location at input with three levels: 4, 8 and 12 inches; and 2) the distance moved to the location at output with 2 levels: 1/4 and 3/4 of the distance moved at input. There was no statistical difference between the levels of these factors.

Discussion

To this point, the retention of K-location information had been studied either with short retention intervals or with only absolute error as the dependent variable. This study was an attempt to determine the maximal period of time K-location information could be retained when recall performance is measured by absolute, constant and variable error measurements. Also, the results of this experiment will serve as a basis for selecting an appropriate retention interval to be used in experiment III.

The effect of length of delay

The results obtained from the main effect of recall delay were not in accord with the first hypothesis. There was no statistical difference in recall performance after 0, 10 and 20 second delays (figures 7, 8 and 9). For this type of task, the maximum recall delay used when performance was evaluated by the three dependent variables was 12 seconds (Laabs, 1971). No recall decrement was observed in Laabs' study. However, results obtained from absolute error measurements alone (Hughes, 1969) indicated that this type of informa-

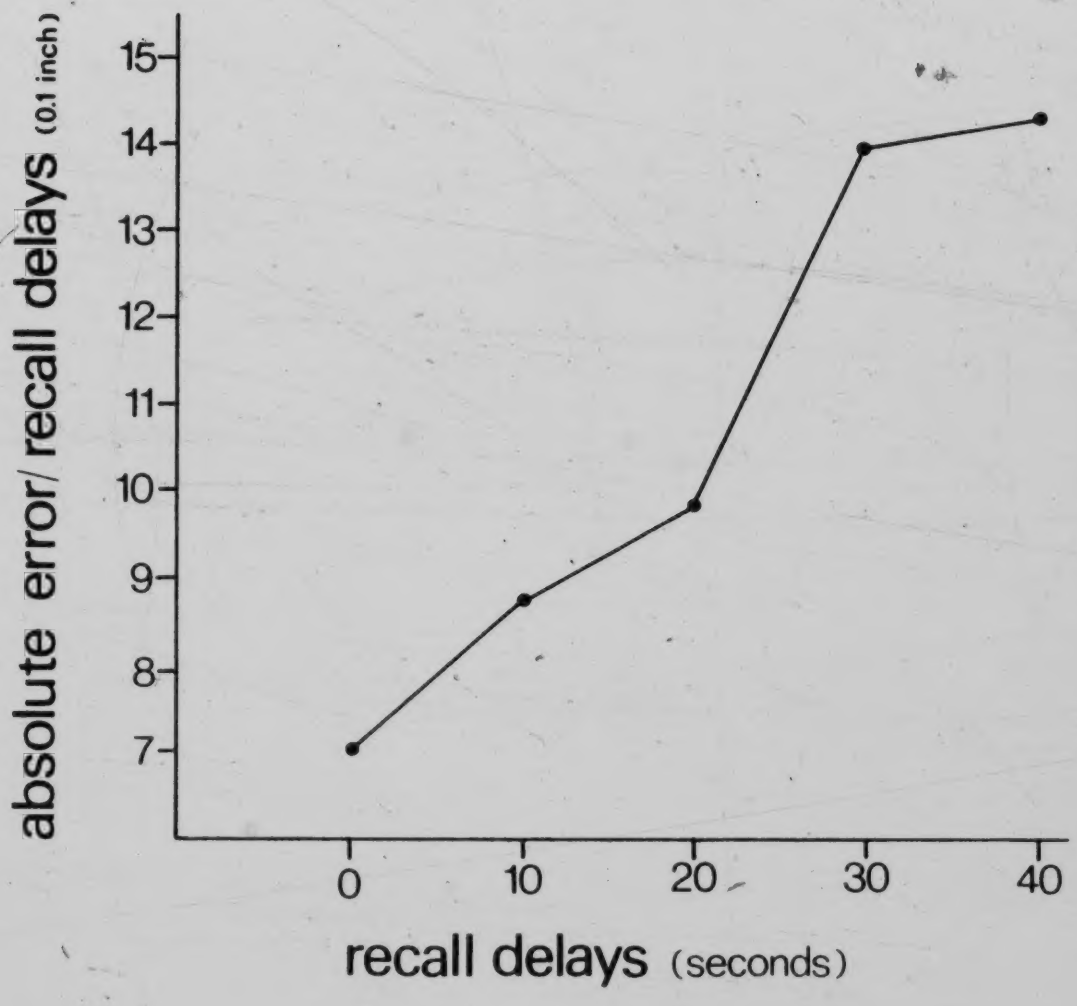


FIGURE 7: THE MEAN ABSOLUTE ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATION AS A FUNCTION OF THE LENGTH OF RECALL DELAY.

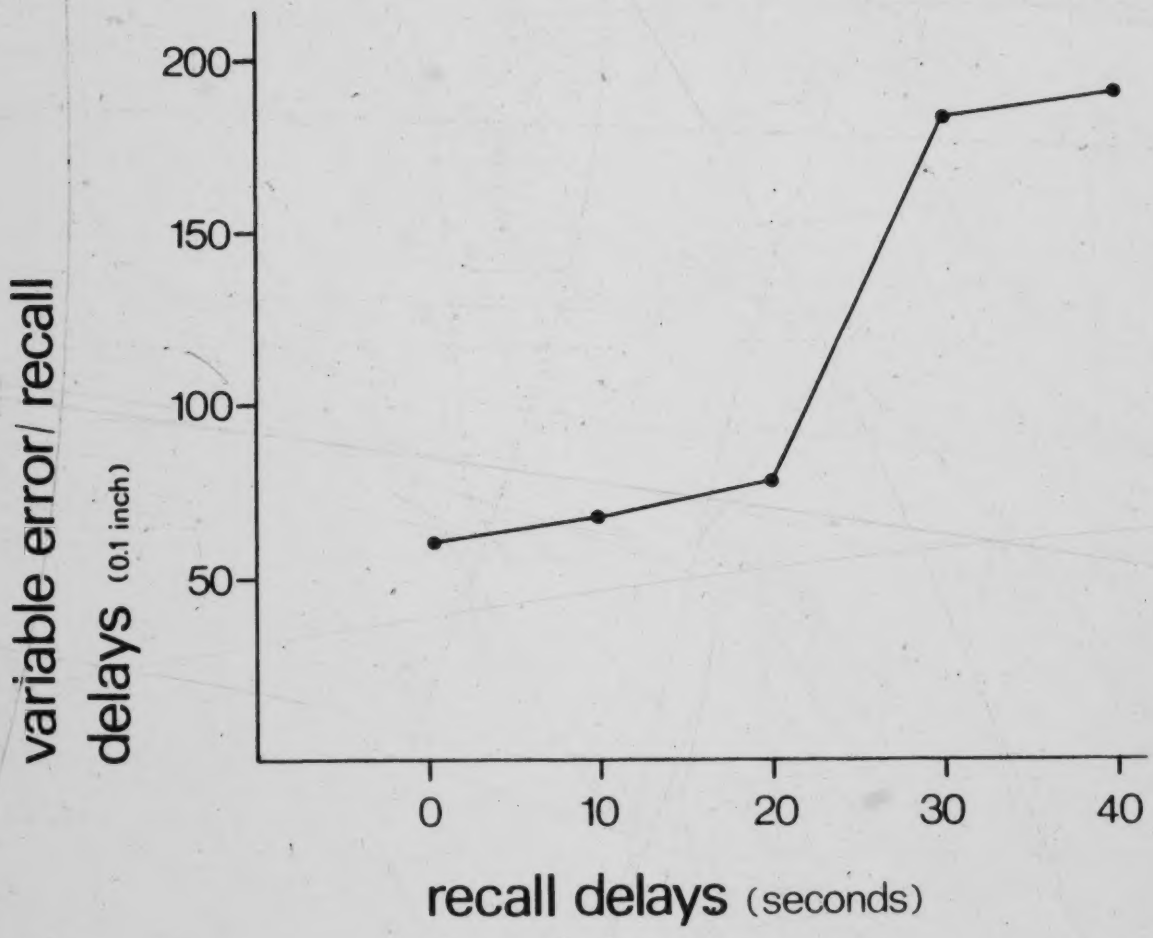


FIGURE 8: THE MEAN VARIABLE ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATION AS A FUNCTION OF THE LENGHT OF THE RECALL DELAY.

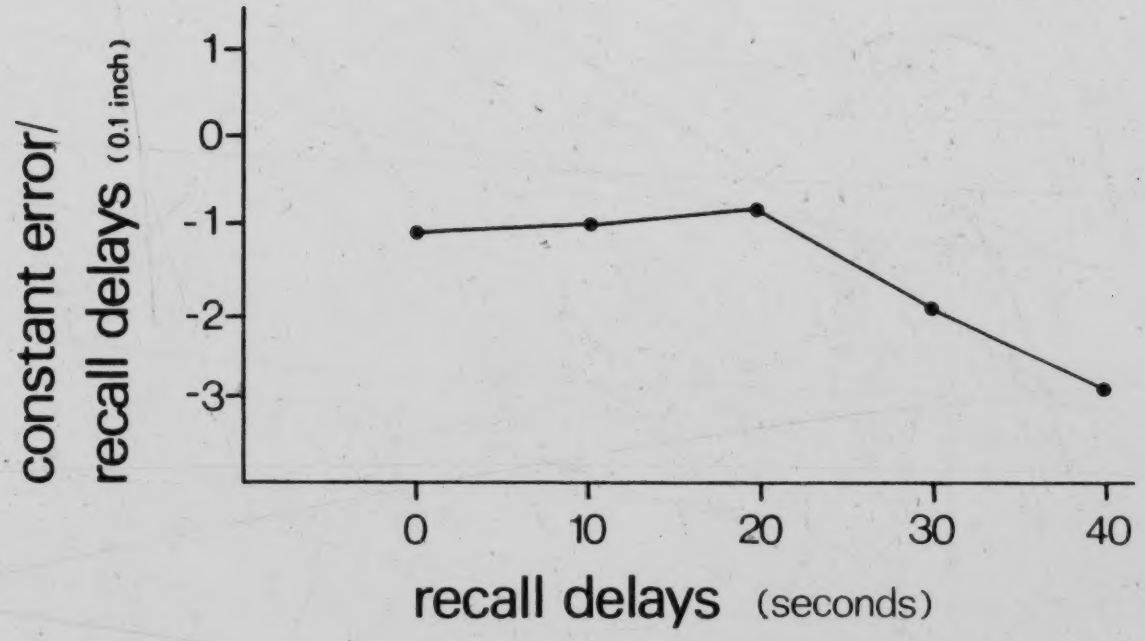


FIGURE 9: THE MEAN CONSTANT ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATION AS A FUNCTION OF THE LENGHT OF RECALL DELAY.

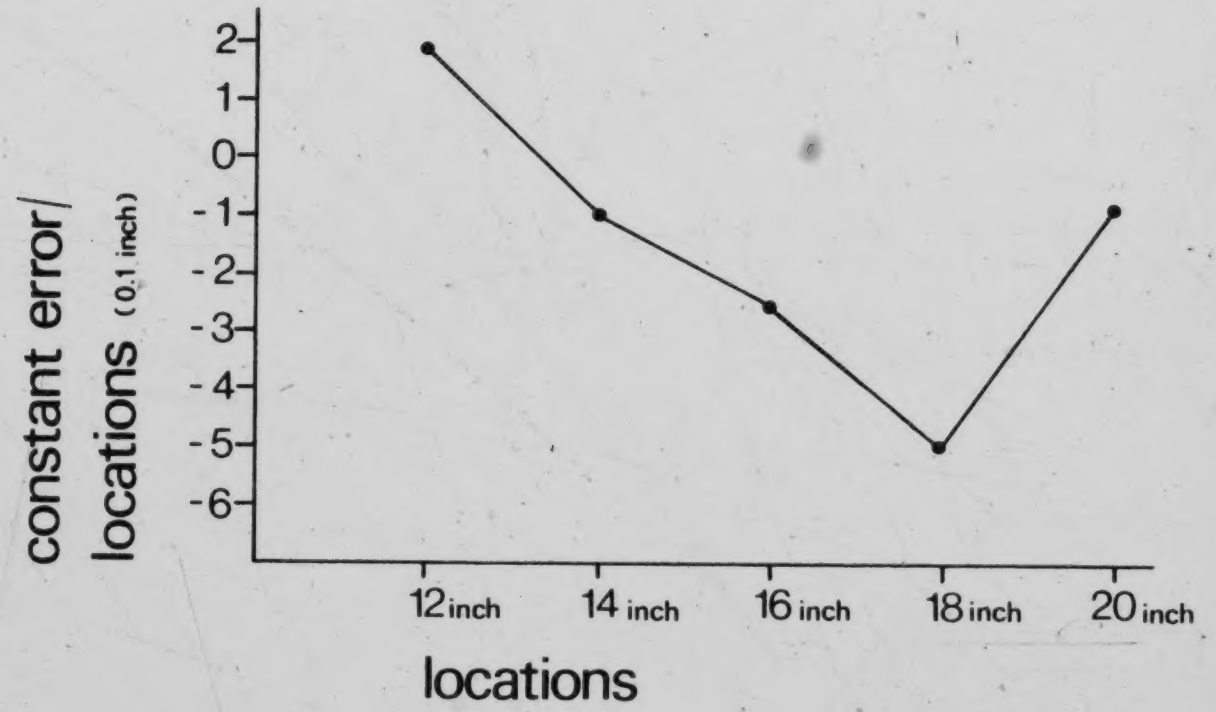


FIGURE 10: THE MEAN CONSTANT ERROR FOR RECALL PERFORMANCE OF THE FIVE RESPECTIVE LOCATIONS USED.

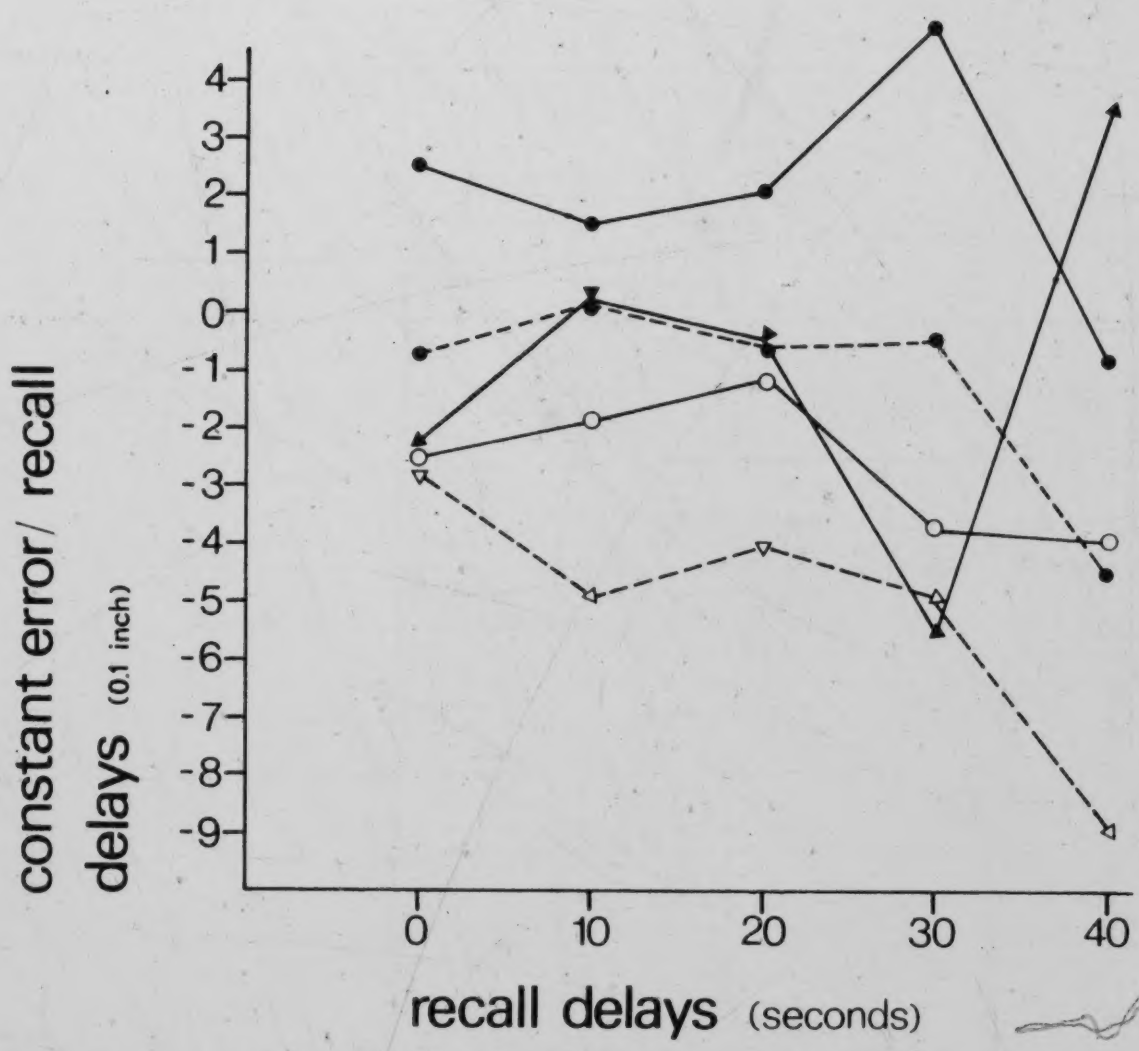


FIGURE 11: THE MEAN CONSTANT ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATIONS AS A FUNCTION OF THE LENGHT OF THE RECALL DELAY.

12 INCH LOCATION
14 INCH LOCATION
16 INCH LOCATION
18 INCH LOCATION
20 INCH LOCATION

tion could be retained for a longer period of time. In the present study, when recall delays were greater than 20 seconds, an abrupt loss of information manifested itself as an increase in variable error while constant error remained statistically unchanged.

Therefore, K-location information can be retained intact for 20 seconds; its loss occurs rapidly and is manifested by an increase in the variability of Ss responses. Based on this evidence a retention interval of 20 seconds was chosen for the retention conditions of the third experiment.

Determining how long K-location information could be maintained was an essential pre-requisite for experiment III. In chapter II, it has been underlined that, if the retention interval was long enough so that Ss could not maintain the fidelity of the criterion information, chances were that the difference between the effect of an interpolated activity and a rest on kinesthetic recall will be non-existent. In such a case, both the effect of the interpolated activity and the effect of time-in-store would be confounded. In experiment III, the effect of different interpolated activities on the recall of K-location were compared. In order to avoid the above mentioned confounding, it was important to establish how long Ss could maintain the fidelity of K-location and then, select the duration of the retention interval appropriately.

Subsidiary problem: the effect of the distance moved to a location at input and at output

The fact that recall performance of the criterion

location was independent of the distance moved at input or at output shows that it really was the end point of the criterion movement (i.e. the criterion location) that was stored and that Ss ignored the distance travelled to get there. This demonstrates that the methodology used in this experiment to isolate location as the only reliable cue was successful.

Experiment 3

Hypotheses

H_1: Errors for immediate recall = errors for recall after 20 seconds < errors after 20 seconds of verbal interpolated task for absolute, constant and variable error scores.

H_2: Errors for recall after 20 seconds of verbal interpolated task < errors for recall of verbal interpolated task + K-interpolated location for constant error scores.

H_3: Errors for recall after verbal interpolated task + K-interpolated location = errors for recall after K-interpolated location for constant error scores.

The first hypothesis was formed to demonstrate that recall performance would deteriorate if Ss were not allowed to attend to the criterion information during the retention interval. Such an effect was reported in studies using absolute error as the dependent variable (Wilberg, 1969; Hughes, 1969; Moyst, 1969). Since absolute error is a redundant statistic, the additional use of constant and variable errors would indicate how the effect of removal of attention would manifest itself for the Ss used in this study. This was necessary for the purpose of subsequent comparisons.

The second hypothesis was formed to demonstrate that the simultaneous effect of a verbal interpolated task and of a K-interpolated location would produce a shift in Ss response

biases at recall which would not be present when a verbal interpolated task would be the only interpolated activity. This prediction was based on available evidence of the effect of K-interpolated movements (Craft and Hinrichs, 1971; Patrick, 1971; Stelmach, 1969).

The third hypothesis was formed to show whether a K-interpolated location, when attended to, would have a greater affect on recall performance than a K-interpolated location that could not be attended to. This hypothesis was stated in the null form because of the unavailability of evidence concerning this phenomenon.

Results

Three 3-way analyses of variance were carried out on the absolute, constant and variable error scores as the dependent variables (tables 7, 8 and 9 respectively). A statistical model after Edwards (1972, p. 273) was used to determine the experimental error to test the main effects.

The main effect of retention conditions was significant at the 0.01 level of significance for absolute, constant and variable error. Further, when applying the Greenhouse and Geiser (1959) conservative degrees of freedom, the F values obtained from absolute and constant error measurements remained significant ($F(1,9) = 12.95$: $P < 0.01$) and ($F(1,9) = 15.18$: $P < 0.01$) respectively. Alternately the F-ratio obtained from variable error measurements remained significant at the 0.05 level of significance ($F(1,9) = 8.25$: $P < 0.025$). The graphs for

this main effect were illustrated in figures 12, 13 and 14 respectively. The means of this main effect were reported in appendix C, table 24.

The main effect of location was significant for constant error only with both normal ($F(4,36 = 5.86$: $P < 0.01$) and conservative degrees of freedom ($F(1,9) = 5.86$: $P < 0.05$). The graphs for this main effect for constant error were illustrated in figure 15.

In all three analyses, the retention conditions X location interaction was not statistically significant.

Scheffé's test was applied to the means of the levels of retention conditions for absolute, constant and variable error scores respectively (appendix C, table 26). For absolute error scores Scheffé's test yielded the following results: 0 delay was different than 20 seconds of verbal IT and from K-interpolated location + verbal IT, and also from K-interpolated location. Also, 20 seconds of rest was different from K-interpolated location + verbal IT. For constant error scores Scheffé's test yielded the following results: 0 delay was different from 20 seconds of verbal IT + K-interpolated location and from K-interpolated location; 20 seconds of rest differed from 20 seconds of verbal IT + K-interpolated location and from K-interpolated location. And also, 20 seconds of verbal IT differed from 20 seconds of verbal IT + K-interpolated location and from K-interpolated location. For variable error, Scheffé's test yielded the following results: both 0 and 20 second delays differed from 20 seconds of verbal IT. Also, 20 seconds of

Table 7

Three-way Analysis of Variance
Absolute Error

Source	Sum of Squares	df	Mean Squares	F
Retention conditions (A)	2,018.382	4	504.595	12.95**
A X C	1,402.721	36	38.964	
Locations (B)	40.178	4	10.044	0.26
B X C	1,351.820	36	37.550	
Subjects (C)	692.020	9	76.891	
A X B	227.178	16	14.198	0.94
A X B X C	2,165.909	144	15.041	

Table 8

Three-way Analysis of Variance
Constant Error

Source	Sum of Squares	df	Mean Squares	F
Retention conditions (A)	6,720.022	4	1,680.005	15.18**
A X C	3,981.642	36	110.601	
Locations (B)	1,202.365	4	300.591	5.86**
B X C	1,844.586	36	51.238	
Subjects (C)	7,649.502	9	849.894	
A X B	497.446	16	31.090	0.99
A X B X C	4,516.216	144	31.362	

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 9

Three-way Analysis of Variance
Variable Error

Source	Sum of Squares	df	Mean Squares	F
Retention conditions (A)	646,347.50	4	161,596.87	8.25**
A X C	704,819.31	36	19,578.31	
Locations (B)	14,602.04	4	3,650.51	0.24
B X C	536,849.56	36	14,912.48	
Subjects (C)	294,974.75	9	32,774.96	
A X B	101,927.00	16	6,370.43	0.72
A X B X C	1,264,517.00	144	8,781.36	

* Significant at the 0.05 level

** Significant at the 0.01 level

verbal IT differed from K-interpolated condition.

Scheffé's test was also applied to the means of the levels of location for constant error scores (appendix C, table 37). Performance under the 12 inch location differed from that of under the 18 inch location.

Discussion

The effect of verbal IT

As illustrated from the results obtained from absolute error measurements, indulging in the verbal IT for 20 seconds caused a significant decrement in recall performance when it is compared with immediate recall performance. Those results are in accordance with the related literature (Wilberg, 1969; Hughes, 1969; Moyst, 1969). This decrement in recall performance due to verbal IT could not be explained by a shift in Ss response biases since, when constant error scores were analysed, no difference was found between the effect of immediate recall, 20 seconds of rest and 20 seconds of verbal interpolated activity. However, examination of variable error scores revealed that the effect of verbal IT manifested itself as an increase in the variability of Ss responses. In fact, while there was no difference between immediate recall performance and that of after 20 seconds of rest, variable error scores were significantly greater after the verbal IT condition than they were after two previous conditions. The consistency of this effect is further evidenced by the fact that the performance of every S shows the same trend (appendix C, table 25).

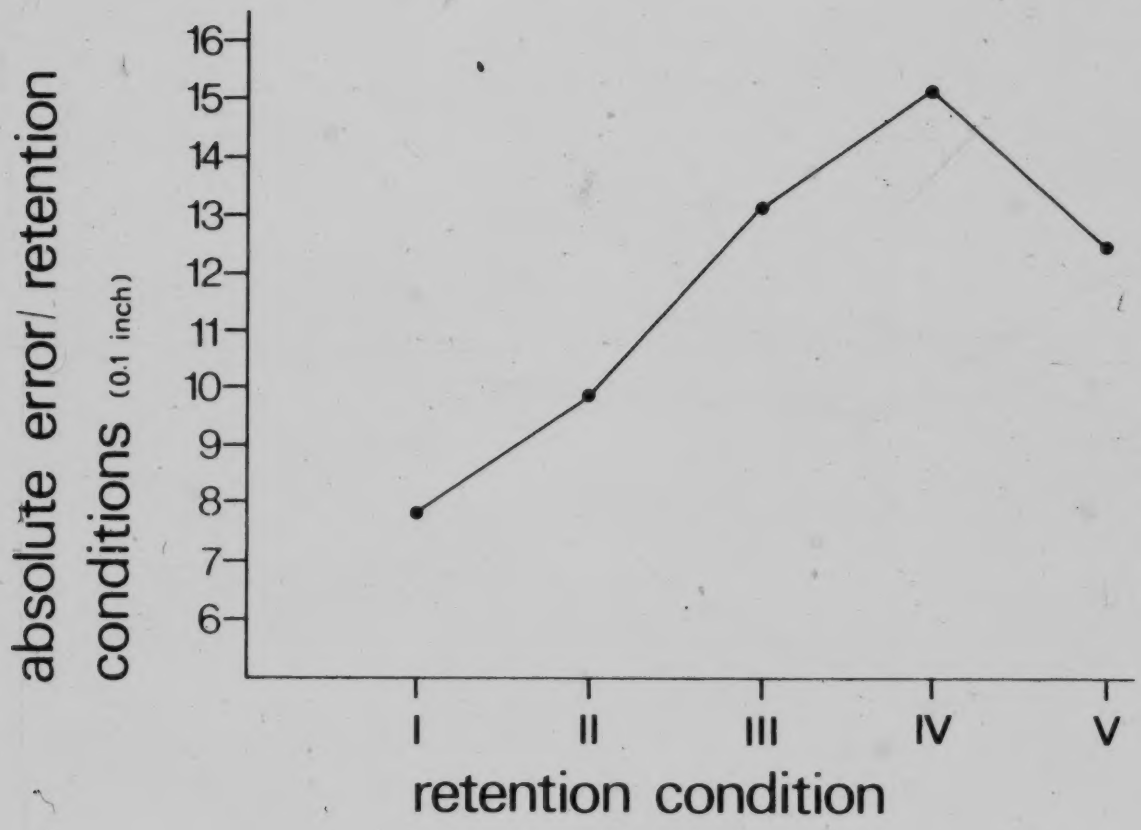


FIGURE 12: THE MEAN ABSOLUTE ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATION AS A FUNCTION OF THE RETENTION CONDITIONS.

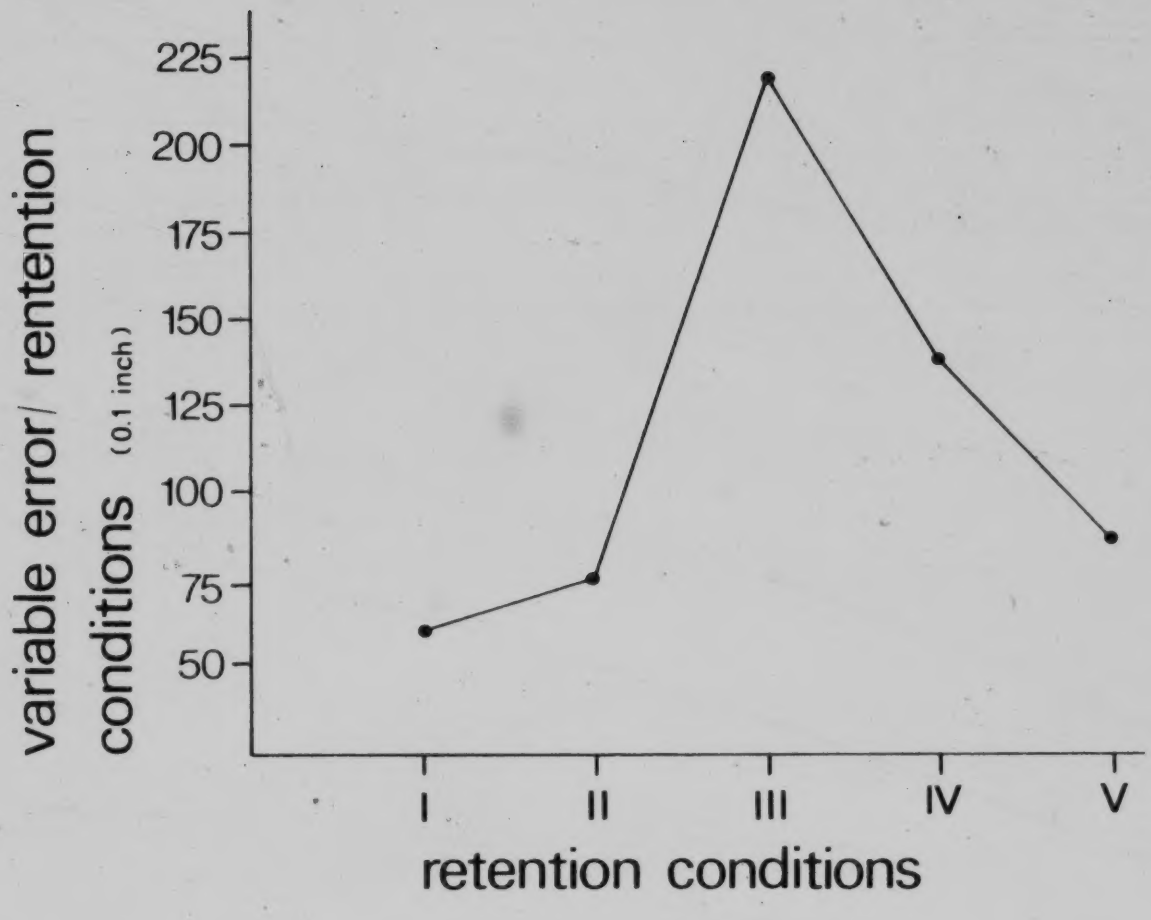


FIGURE 13: THE MEAN VARIABLE ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATION AS A FUNCTION OF THE RETENTION CONDITIONS.

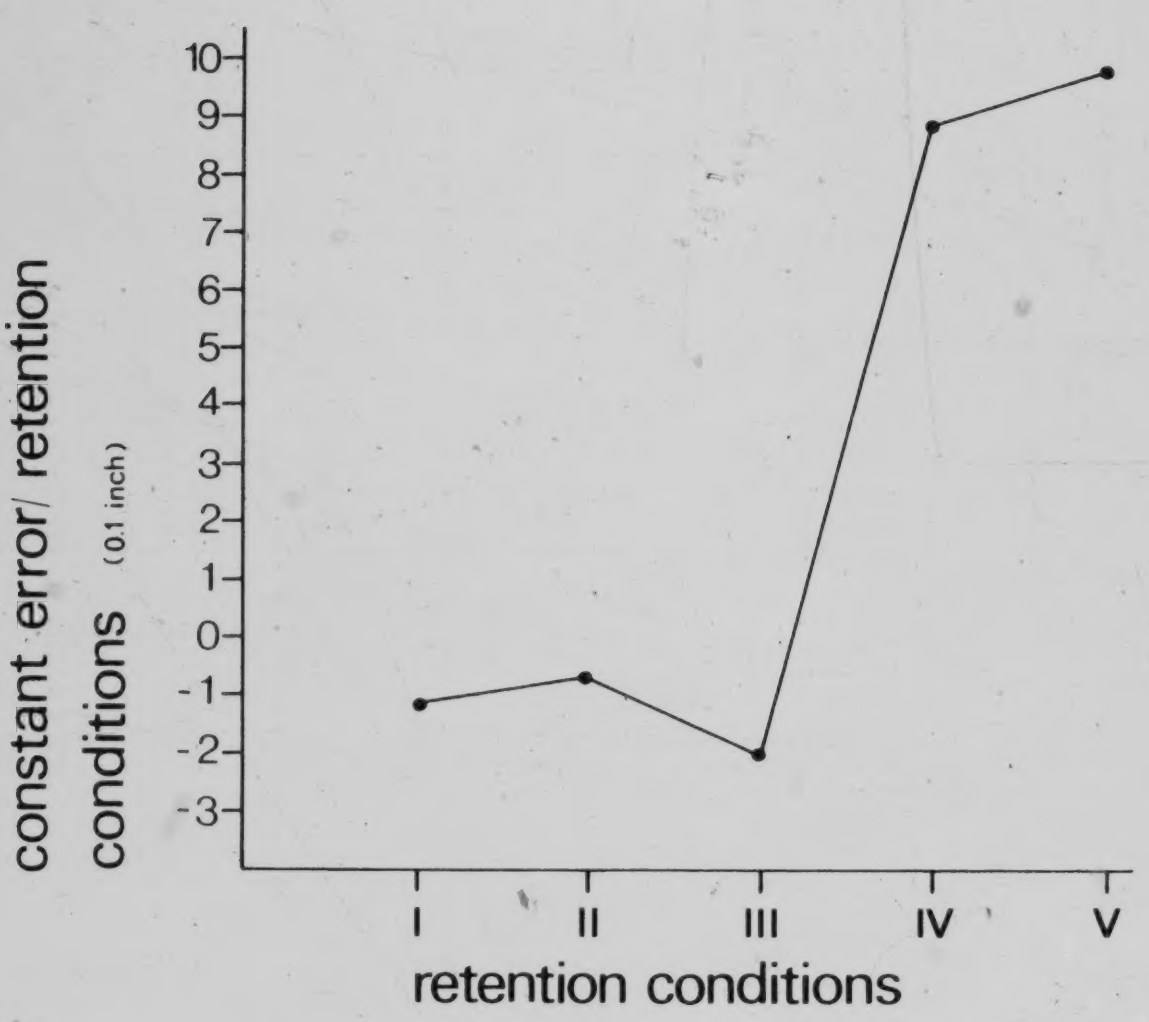


FIGURE 14: THE MEAN CONSTANT ERROR FOR RECALL PERFORMANCE OF THE CRITERION LOCATION AS A FUNCTION OF THE RETENTION CONDITIONS.

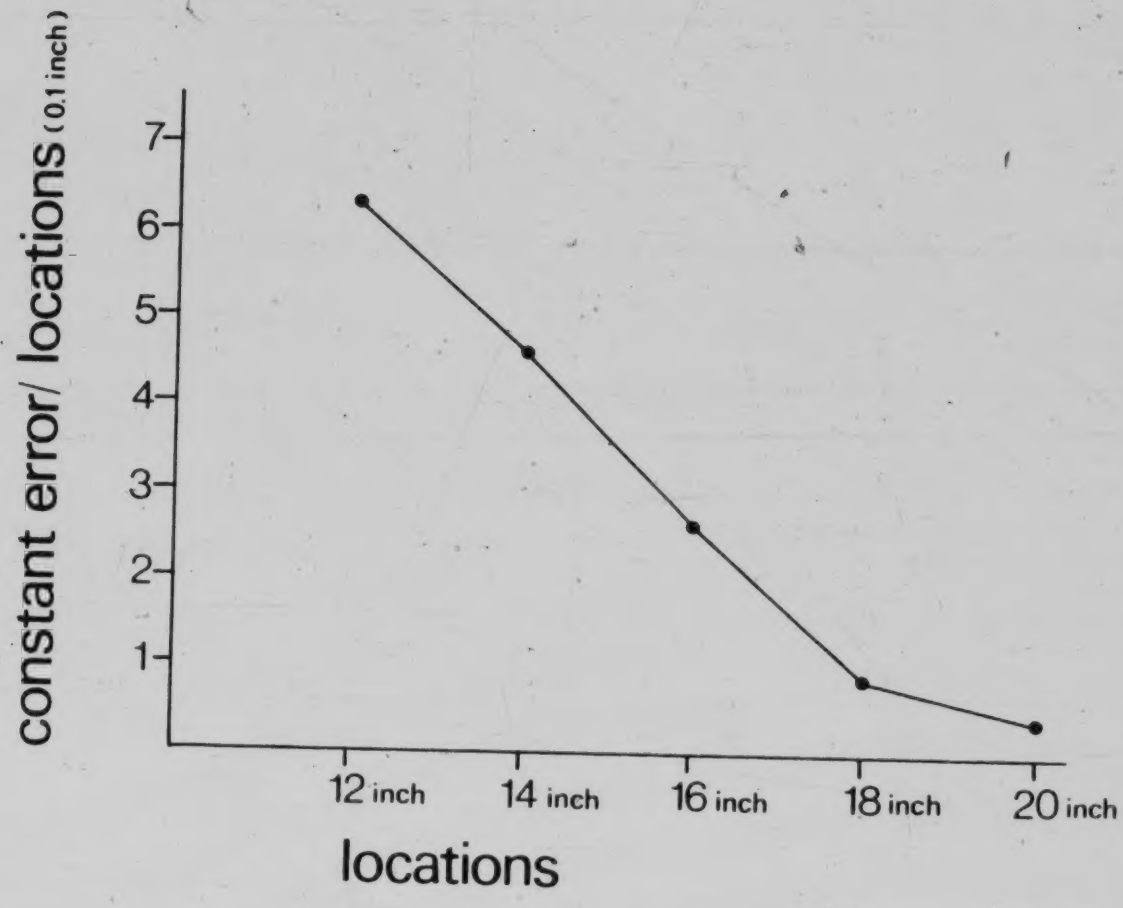


FIGURE 15: THE MEAN CONSTANT ERROR FOR EVERY CRITERION LOCATION.

Laabs (1971) and Keele and Ells (1972) also found a similar effect of verbal IT.

Those results are indicative of the fact that, in order to maintain the fidelity of K-location information, the S needs his attention during the retention interval. According to Broadbent's view (1958), rehearsal is a recycling process which requires a portion of the limited processing capacity of the S. Posner and Konick (1966) rightfully suggested that it would be meaningful to talk about rehearsal of material in nonverbal form if it were shown to require a portion of the Ss processing capacity. From the results of the present experiment, it can be said that, indeed, the maintenance of the fidelity of K-location information requires a portion of the Ss processing capacity. Although rehearsal demands a portion of the limited information processing capacity of the Ss, it may be based on different processes. Thus in verbal tasks it may involve covert speech while in kinesthetic memory something more akin to concentration may be appropriate (Posner, 1967b). This brings the question of how does S use his attention to maintain the fidelity of K-location information. This question will be discussed next.

The simultaneous effect of verbal IT and K-interpolated location

Since S uses his attention to maintain the fidelity of K-location information, how does he use it? Does he consciously use his attention to transform the criterion material

into a more retainable form? or does S simply concentrate on the sensory information as received without transforming it at all?

In order to answer this question, two experimental conditions were compared: the effect of verbal IT during the retention interval was compared with the simultaneous effect of verbal IT and of a K-interpolated location. If, in addition to diverting Ss attention during the retention interval, a K-interpolated location was passively presented at the same time, Ss could not consciously transform this K-interpolated material and it would be put into the system in an untransformed manner. If this raw information would disrupt the original criterion location, it would show that the criterion K-location was not transformed for rehearsal purposes but was stored in its original form.

First, results obtained from absolute error measurements indicated that those two experimental conditions did not differently affect recall performance. Analysis of variable error scores revealed the same finding. However, constant error measurements indicated clearly that the addition of a K-interpolated location had a statistically significant effect on recall performance. When the K-interpolated location was presented simultaneously with the verbal IT, Ss recall performance was characterized by a significant shift in their responses, which effect was not present when verbal IT alone was introduced during the retention interval. This shift occured in the direction of the K-interpolated location which was always

5 inches further than the criterion location. Since Ss could not be aware of the K-interpolated location because their attention was diverted by the verbal IT, this interpolated K-location was stored without being consciously transformed. Since the recall of the K-criterion location was affected by this raw interpolated material, it indicates that the criterion information was also stored untransformed. Those results are suggestive of the fact that, during the retention interval, Ss use their attention to concentrate on the K-criterion information without transforming it. This conclusion, however, cannot be generalized to all of the ten subjects used in this experiment. While seven of the ten Ss exhibited a shift in their response biases due to the simultaneous effect of the verbal IT and the K-interpolated location, three Ss did not seem to be affected at all (appendix C, table 25). A detailed inspection of individual results could not suggest any interpretation of such a selectivity in the treatment effect.

In this experiment, the validity of the comparison between the effect of verbal IT alone and that of the simultaneous presentation of K-interpolated location and verbal IT rests upon the effectiveness of the verbal IT as an attention diverter. This effectiveness was statistically tested in the following way. A comparison was made between Ss performance on the verbal shadowing task (described in chapter III, p. 35) when it was used as an interpolated activity within the experimental conditions described above and Ss performance on the same verbal shadowing task when it was executed as a primary

task in a control condition. So three performances were compared: performance on the verbal shadowing task when it was a primary task (control condition); performance on the same shadowing task when it was used as a verbal IT; performance on the same task when it was used as a verbal IT simultaneously with the K-interpolated location.

A 3-way analysis of variance was conducted on those results (appendix C, table 28). It yielded an F-ratio of 4.58 ($P < 0.05$). Scheffé's test was applied to the means and it showed that errors for the control condition were greater than that of the other two conditions. So performance on the verbal shadowing task was better when it was used as an interpolated activity and it can be stated with confidence that Ss really attended to the verbal shadowing task when it was presented as an interpolated activity.

The effect of a K-interpolated location when Ss attention was not diverted during the retention interval

In this experimental condition, S was presented with a criterion location and an alternate location which was always 5 inches further than the criterion location. During the 20 second retention interval Ss attention was not diverted by any verbal IT. This treatment condition was introduced to determine the affect of a K-interpolated location on recall performance when Ss had the opportunity to attend to it.

Results obtained from variable error measurements revealed that the variability of Ss responses was statistically

less under the interpolated location condition than it was under the verbal IT condition. This fact is indicative of more consistent recall performance when attention could be devoted to both the criterion and the interpolated location. Examination of constant error scores revealed that the K-interpolated location condition had the same shifting effect on recall performance than the verbal IT + K-interpolated condition. This shift in Ss response biases was in the direction of the K-interpolated location. Such results tend to demonstrate that the shift in Ss response biases obtained when both the verbal IT and the K-interpolated location were presented during the retention interval was not due to some arbitrary combination of verbal IT with K-interpolated location but, rather, was the sole effect of the K-interpolated location. Also, those results tend to show that a K-interpolated location does not have to be consciously processed in order to have an affect on the recall of K-location information, which would reinforce the point made earlier that the K-criterion information was stored untransformed.

Chapter 5

Summary and Conclusion

Summary

The purpose of this series of three studies was to determine how distance and location cues are used for the retention of kinesthetic information. The experimental design was a treatment by subjects, factorial design with repeated measures. Ss were 10 undergraduate and graduate physical education students between the ages of 15 to 28.

The apparatus consisted of a 1 inch by 48 inch metal rule used as a track, mounted on a baseboard. A cursor 1 inch by 1.5 inches was fitted on the metal track in such a way that it could be moved along the track with minimal friction. The experimental task was for the S to reproduce K-distances or K-locations by displacing the cursor along the track. For the three studies, all factors were analysed using the dependent variables of absolute error, constant error and variable error scores.

For experiment 1, the first factor of experimental interest was retention condition with 4 levels (immediate recall when only the criterion distance was stored, recall after 15 seconds of rest when only the criterion distance was stored, immediate recall when both the criterion and interpolated distances were stored together and recall after 15 seconds when both the criterion and interpolated distances

were stored together). The second factor of interest was distance with two levels (7inch and 12inch). The main effect of retention condition was significant at the 0.01 level of significance for absolute and variable error scores. Immediate recall led to significantly less error ($P < 0.01$) than recall after 15 seconds of rest when only the criterion distance was stored. With constant error scores, a significant retention condition X distance interaction was obtained ($P < 0.01$)

For experiment 2, the factor of experimental interest was recall delays with 5 levels (0, 10, 20, 30, and 40 seconds). It was found that the fidelity of K-location information could be maintained for at least 20 seconds.

For experiment 3, the factor of experimental interest was retention condition with 5 levels (immediate recall, recall after 20 seconds of rest, recall after 20 seconds of verbal interpolated activity, recall after 20 seconds of verbal IT + K-interpolated location and recall after 20 seconds of K-interpolated location). A significant increase in variable error occurred after Ss indulged in 20 seconds of verbal IT; the combined effect of verbal IT + K-interpolated location and also the sole effect of K-interpolated location manifested itself as a significant shift in Ss response biases.

Conclusions

Ss do not appear to be able to make judgments of

distance but rather to be more efficient in making judgments in relationship to their bodies. Furthermore, if, when dealing with K-distance information, the task provides additional information, Ss operate on the basis of this additional information to maximize their performance.

The fidelity of K-location information can be maintained for at least 20 seconds. In order to maintain it Ss have to devote their attention to the untransformed criterion material.

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For the tables of this appendix the retention conditions are defined as follows:

(i) Immediate recall when only the criterion distance was stored.

(ii) Immediate recall when both the criterion and intercalated distances were stored together.

(iii) Recall after 15 seconds of rest when only the criterion distance was stored.

(iv) Recall after 15 seconds of rest when both the criterion and intercalated distances were stored together.

Table 10

Means for Retention Conditions and Distances
for Absolute, Constant and Variable
Error Scores

	Distances	Retention Conditions			
		I	II	III	IV
Absolute	7 inch	[illegible]	[illegible]	[illegible]	[illegible]
Error	12 inch	[illegible]	[illegible]	[illegible]	[illegible]
	Mean	[illegible]	[illegible]	[illegible]	[illegible]
Constant	7 inch	[illegible]	[illegible]	[illegible]	[illegible]
Error	12 inch	[illegible]	[illegible]	[illegible]	[illegible]
	Mean	[illegible]	[illegible]	[illegible]	[illegible]
Variable	7 inch	[illegible]	[illegible]	[illegible]	[illegible]
Error	12 inch	[illegible]	[illegible]	[illegible]	[illegible]
	Mean	[illegible]	[illegible]	[illegible]	[illegible]

Table II

Individual Subjects' Scores (Constant Error) Obtained on the Recall Performance of the 12 Inch Distance under Each of the Experimental Conditions

Subjects	Retention Conditions		
	I	II	III
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
Means	[illegible]	[illegible]	[illegible]

Table 12

Individual Subjects' Scores (Constant Error) Obtained on the Recall Performance of the 7 inch Distance under Each of the Experimental Conditions

Subjects	Retention Conditions			
	I	II	III	IV
1	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]

Table 11

Three-way Analysis of Variance
Absolute Error

Source	Sum of Squares	df	Mean Squares	F
Order (A)	[illegible]	[illegible]	[illegible]	[illegible]
A x [illegible]	[illegible]	[illegible]	[illegible]	
Instructions (B)	[illegible]	[illegible]	[illegible]	[illegible]
A x B	[illegible]	[illegible]	[illegible]	
Subjects (C)	[illegible]	[illegible]	[illegible]	
A x C	[illegible]	[illegible]	[illegible]	[illegible]
B x C	[illegible]	[illegible]	[illegible]	

Table 12

Three-way Analysis of Variance
Constant Error

Source	Sum of Squares	df	Mean Squares	F
Order (A)	[illegible]	[illegible]	[illegible]	[illegible]
A x [illegible]	[illegible]	[illegible]	[illegible]	
Instructions (B)	[illegible]	[illegible]	[illegible]	[illegible]
A x B	[illegible]	[illegible]	[illegible]	
Subjects (C)	[illegible]	[illegible]	[illegible]	
A x C	[illegible]	[illegible]	[illegible]	[illegible]
B x C	[illegible]	[illegible]	[illegible]	

* Significant at the [illegible] level

** Significant at the [illegible] level

Table 15

Three-way Analysis of Variance
Variable Error

Source	Sum of Squares	df	Mean Squares	F
Order (A)	[illegible]	1	[illegible]	[illegible]
A x C	[illegible]	[illegible]	[illegible]	
Distances (B)	[illegible]	[illegible]	[illegible]	[illegible]
B x C	[illegible]	[illegible]	[illegible]	
Subjects (C)	[illegible]	[illegible]	[illegible]	
C x B	[illegible]	[illegible]	[illegible]	[illegible]
C x B x C	[illegible]	[illegible]	[illegible]	

* Significant at the 0.01 level

** Significant at the 0.01 level

Table 16

Scheffé's Tests Applied to Differences Between
[illegible] Means for Distance Reproduction for
Absolute and Variable Error Scores

Absolute Error

Retention Conditions

	I	II	III	IV	Smallest Significant Differences
Means	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]**	[illegible]	
[illegible]			[illegible]	[illegible]	[illegible] at [illegible]
[illegible]				[illegible]*	[illegible] at [illegible]

Variable Error

Retention Conditions

	I	II	III	IV	Smallest Significant Differences
Means	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]**	[illegible]	
[illegible]			[illegible]*	[illegible]	[illegible] at [illegible]
[illegible]				[illegible]	[illegible] at [illegible]

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 17

Two-way Analysis of Variance for Recall Performance of 12 inch Distance Constant Error

Source	Sum of Squares	df	Mean Squares	F
Retention Conditions (A)	775.1947	1	258.5115	1.1424
Subjects (B)	1,615.958	9	401.7731	
A x B	5,903.1717	27	218.6434	
TOTAL	10,294.9264	39		

Table 18

Two-way Analysis of Variance for Recall Performance of 7 inch Distance Constant Error

Source	Sum of Squares	df	Mean Squares	F
Retention Conditions (A)	438.2127	1	146.07	4.071*
Subjects (B)	4,751.8576	9	527.9841	
A x B	1,284.1713	27	47.5619	
TOTAL	6,474.2416	39		

* Significant at the 0.05 level

Appendix B

Table 14

Means for Recall Delays and Locations for Absolute, Constant and Variable Error Scores

	Location	Recall Delays				
		0 sec	10 sec	20 sec	30 sec	40 sec
Absolute Error	12 inch	7.74	9.06	9.08	11.30	13.32
	14 inch	6.58	8.40	9.50	11.90	13.56
	16 inch	7.46	9.54	11.04	15.54	12.94
	18 inch	6.18	9.12	9.67	16.52	15.18
	20 inch	7.46	8.42	9.80	14.76	13.10
	MEAN	7.08	8.70	9.81	14.04	14.10
Constant Error	12 inch	2.42	1.52	2.16	4.86	-0.96
	14 inch	-0.70	0.16	-0.68	-0.54	-4.66
	16 inch	-2.57	-1.82	-1.10	-3.68	-3.94
	18 inch	-2.74	-4.84	-4.02	-4.80	-8.82
	20 inch	-2.28	-0.08	-0.50	-5.64	3.62
	MEAN	-1.17	-1.01	-0.828	-1.96	-2.95
Variable Error	12 inch	63.15	64.76	64.31	154.99	206.12
	14 inch	48.05	70.168	75.92	77.05	201.03
	16 inch	62.11	62.656	85.51	225.11	187.74
	18 inch	56.64	78.184	85.93	250.14	200.52
	20 inch	67.71	65.24	74.48	194.09	155.66
	MEAN	59.53	68.20	77.22	180.27	190.10

Table [illegible]

Scheffe's Tests Applied to Differences Between
[illegible] Means for Recall Delays for Absolute,
and Variable Error Scores

Absolute Error

Recall Delays

	0 sec	10 sec	20 sec	30 sec	40 sec	Smallest Significant Differences
Means	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]	[illegible]	[illegible]**	[illegible]**	
[illegible]			[illegible]	[illegible]**	[illegible]**	[illegible] at [illegible]
[illegible]				[illegible]*	[illegible]*	[illegible] at [illegible]
					0.26	

Variable Error

Recall Delays

	0 sec	10 sec	20 sec	30 sec	40 sec	Smallest Significant Differences
Means	59.93	68.20	77.22	180.27	190.10	
59.93		8.27	17.29	120.34**	130.17**	
68.20			9.02	112.07**	121.90**	87.38 at 0.05
77.22				103.105*	112.88**	105.45 at 0.01
180.27					9.83	

* Significant at the 0.05 level

** Significant at the 0.01 level

Table [illegible]

Scheffe's Tests Applied to Differences Between
[illegible] Means for Location for
Constant Error

	Locations					
	12	14	16	18	20	Smallest Significant Differences
Means	1.44	1.01	2.60	5.03	0.82	
1.44		2.45	4.18	6.47**	2.76	
1.01			1.59	4.02	0.19	5.11 at 0.05
2.60				1.43	1.78	6.47 at 0.01
5.03					4.21	

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 20

Three-way Analysis of Variance
Constant Error

Source	Sum of Squares	df	Mean Squares	F
Distance Output (A)	[illegible]	[illegible]	[illegible]	[illegible]
A X C	[illegible]	[illegible]	[illegible]	
Distance Input (B)	[illegible]	[illegible]	[illegible]	[illegible]
B X C	[illegible]	[illegible]	[illegible]	
Subjects (C)	[illegible]	[illegible]	[illegible]	
A X B	[illegible]	[illegible]	[illegible]	[illegible]
A X B X C	[illegible]	[illegible]	[illegible]	

Table 21

Three-way Analysis of Variance
Variable Error

Source	Sum of Squares	df	Mean Squares	F
Distance Output (A)	463.14	1	463.14	0.50
A X C	8,267.109	9	918.56	
Distance Input (B)	4,499.44	2	2,249.72	2.11
B X C	19,176.77	18	1,065.37	
Subjects (C)	34,101.78	9	3,789.08	
A X B	936.16	2	468.08	0.62
A X B X C	13,423.86	18	745.77	

* Significant at the 0.05 level

** Significant at the 0.01 level

Appendix C

For the tables of this appendix the retention conditions are defined as follows:

I Immediate recall

II Recall after 20 seconds of rest

III Recall after Ss have indulged in a verbal interpolated task for 20 seconds

IV Recall after a 20 second retention interval during which Ss engaged in a verbal interpolated and were, at the same time, presented with a passive K-interpolated location

V Recall after Ss were presented with a passive K-interpolated location for 20 seconds.

Table 14

Means for Retention Conditions and Locations for Absolute, Constant and Variable Error Scores

	Locations	Retention Conditions				
		I	II	III	IV	V
Absolute Error	12	7.74	9.08	12.36	16.76	11.32
	14	6.58	9.50	11.72	16.00	14.88
	16	7.46	11.04	13.18	15.58	12.70
	18	6.18	9.67	13.82	13.84	10.50
	20	7.46	9.80	14.82	13.86	12.58
	MEAN	7.084	9.818	13.18	15.20	12.396
Constant Error	12	2.42	2.16	2.90	13.34	9.98
	14	-0.70	-0.68	0.40	11.04	13.20
	16	-2.57	-1.10	-1.78	9.34	9.32
	18	-2.74	-4.02	-5.56	6.52	10.18
	20	-2.28	-0.50	-6.18	4.48	6.16
	MEAN	-1.174	-0.828	-2.044	8.944	9.768
Variable Error	12	63.15	64.31	196.98	101.596	68.85
	14	48.05	75.92	185.68	202.20	81.62
	16	62.11	85.51	215.38	132.95	112.50
	18	56.64	85.93	229.168	101.91	84.52
	20	67.71	74.48	281.03	128.904	79.73
	MEAN	59.53	77.22	221.647	133.51	85.44

Table 25

Subjects' Average Scores for Each of the Five Retention Conditions for Constant and Variable Error Scores

Constant Error

Subjects	Retention Conditions I	II	III	IV	V
1	-3.6	-5.6	-1.00	14.24	7.0
2	2.6	-1.44	-0.4	15.72	15.16
3	3.52	-0.4	7.56	15.56	15.92
4	4.16	13.52	-0.88	20.88	19.04
5	-1.56	-1.08	-6.36	7.44	12.4
6	-4.74	-3.08	3.36	1.56	7.68
7	-5.00	-7.28	-4.6	12.60	10.92
8	-3.32	-10.08	-19.08	-8.48	-6.24
9	-6.36	-1.88	-1.52	-3.28	1.08
10	-2.56	9.04	2.48	13.20	14.72
MEAN	-1.174	-0.828	-2.044	8.944	9.768

Variable Error

Subjects	Retention Conditions I	II	III	IV	V
1	27.488	24.944	256.56	122.76	94.00
2	26.768	30.096	126.928	62.864	86.624
3	31.808	36.816	525.84	114.96	59.488
4	60.364	84.848	118.816	48.128	67.336
5	88.24	77.98	90.656	106.528	59.088
6	47.552	127.696	160.096	191.664	41.072
7	22.608	96.992	136.384	261.008	117.42
8	74.352	111.468	192.704	130.208	104.64
9	85.536	66.312	121.728	135.74	136.928
10	130.168	115.104	486.79	161.28	87.87
MEAN	59.53	77.22	221.647	133.51	85.44

Table 26

Scheffé's Tests Applied to Differences Between K = 5 Means for Retention Conditions for Absolute, Constant and Variable Error Scores

Absolute Error

	Retention Conditions					
	I	II	III	IV	V	Smallest Significant Differences
MEANS	7.084	9.818	13.18	15.20	12.396	
7.084		2.73	6.09**	8.11**	5.31**	
9.818			3.36	5.38**	2.57	
13.180				2.02	0.78	4.01 at 0.05
					2.80	4.88 at 0.01

Constant Error

	I	II	III	IV	V	Smallest Significant Differences
MEANS	-1.174	-0.828	-2.044	8.944	9.768	
-1.174		0.34	0.86	9.76**	10.93**	
-0.828			1.21	9.76**	10.58**	
-2.044				10.98**	11.80**	6.80 at 0.05
8.944					0.81	8.21 at 0.01

Variable Error

	I	II	III	IV	V	Smallest Significant Differences
MEANS	59.53	77.22	221.647	133.51	85.44	
59.53		17.69	162.11**	73.98	25.91	
77.22			144.42	56.29	8.22	
221.647				88.13	136.20**	90.65 at 0.05
133.51					48.07	109.4 at 0.01

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 27

Scheffé's Tests Applied to Differences Between
K = 5 Means for Location Conditions
for Constant Error

Constant Error						
	Locations					
	12	14	16	18	20	Smallest Significant Differences
Means	6.16	4.65	2.64	0.87	0.33	
6.16		1.51	3.52	5.29*	5.83**	
4.65			2.01	3.78	4.32	
2.64				1.77	2.31	4.60 at 0.05
0.87					0.54	5.59 at 0.01

* Significant at the 0.05 level

** Significant at the 0.01 level

Table 28

Three-way Analysis of Variance
for Error Scores on the
Verbal Shadowing Task

Source	Sum of Squares	df	Mean Squares	F
Conditions (A)	60.45	2	30.22	4.58*
A X C	118.77	18	6.59	
Trials (B)	137.26	24	5.72	0.94
B X C	1,302.97	216	6.03	
Subjects (C)	2,153.38	9	239.26	
A X B	174.28	48	3.63	1.35
A X B X C	1,168.08	432	2.68	

* Significant at the 0.05 level